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Storage and Packaging for an Empire: Agricultural Economics of West-Central Italy, c. 200 BCE-200 CE

Author

Cheung, Caroline

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Storage and Packaging for an Empire: Agricultural Economics of West-Central Italy, c. 200 BCE-200 CE

By

Caroline Man Ting Cheung

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University of California, Berkeley

Committee in Charge:

Professor J. Theodore Peña, Chair
Professor Carlos F. Noreña
Professor Nicholas Purcell
Professor Christine A. Hastorf

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Storage and Packaging for an Empire:
Agricultural Economics of West-Central Italy, c. 200 BCE-200 CE

Abstract

Storage and Packaging for an Empire:
Agricultural Economics of West-Central Italy, c. 200 BCE-200 CE

by

Caroline Man Ting Cheung

Doctor of Philosophy in Ancient History and Mediterranean Archaeology

University of California, Berkeley

Professor J. Theodore Peña, Chair

The emergence of Rome's far-flung territorial empire resulted in a sophisticated regime for the storage and distribution of foodstuffs. This dissertation focuses on a ceramic container used for the storage of wine and oil, the dolium, to investigate how Rome's long-distance, large-scale food supply system impacted craftsmen and agricultural workers in west-central Italy during the period of c. 200 BCE-200 CE. It studies the processes, materials, and skills invested in over three hundred dolia and dolium fragments from Cosa, Pompeii, and Ostia to bring to light the workforces that produced, repaired, used, and maintained these costly investments that were important not only for agriculture, but also food storage in urban settlements. With a lucrative wine market developing overseas, viticultural areas expanded and the demand for wine and large-scale wine fermentation and storage containers exploded. Dolium producers used the same technique (coil-building), but the scale of production differed between the settlements. Potters designed and expanded the dolium, but it was risky and expensive to produce these vessels; dolium production became increasingly subsumed under large *opus doliare* workshops, owned by wealthy aristocrats, senators, and members of the imperial family. By the second century CE, artisans of urban *opus doliare* workshops that produced dolia, bricks, and tile had developed their methods and vessel design in close alignment; the success of these major workshops was so great that the Tiber River Valley had been transformed into antiquity's Ceramic Valley, a hub of ceramic and terracotta production. Building such large vessels, however, was a task fraught with risk, and craftspeople had to develop new methods in their routines, some of which were derived from traditional pottery mending techniques while others were entirely new creations inspired by the architectural industries. The types of damage for dolia, and the methods and materials for their repairs, not only shed light on developments in dolium repair technology, but also on the different workforces. Craftspeople aligned and experimented with their methods, interacting also with the architectural industry to develop new techniques to build these vessels. As the storage regime for Rome became more sophisticated, the utility and importance of dolia extended from production sites to urban settlements, supporting and perhaps even driving raising levels of urbanism. Over time, the very practices and technologies of storage themselves cast a wider net that drew in many potters, architectural workers, farmers, porters, and unskilled workers to propel an ancient global food supply.

For my family.

For Tan Xing Yue.

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Chapter 1 Introduction

Over two thousand years ago, the residents of the city of Rome drank so much wine, that a year's worth would have overfilled the Pantheon.[1] But none of that wine came from Rome, a metropolis too large and densely occupied to produce its own food and drink. Instead, its residents depended on a large-scale food supply system, one that was supported by huge inputs of labor and a complex system of containers, including a bulk ceramic storage container known as a dolium. This large-scale food supply system was vital not only for the city of Rome, but also for sustaining Rome's expanding territory and population.

The emergence of Rome's far-flung territorial empire during the final two centuries BCE fundamentally transformed the Mediterranean region. The population within Italy itself underwent major demographic shifts, with many from the countryside and abroad streaming into the city of Rome.[2] As a result, Rome became the largest metropolis in the Mediterranean world by the first century BCE, reaching a population of one million according to some estimates.[3] The dramatic growth of the city and the attendant demands for resources, such as food and labor, reverberated throughout Italy and stimulated secondary developments in both agricultural production and urbanization. Changing patterns of land use and ownership, the increasingly uneven distribution of wealth, and large influxes of slaves, and the growing use of slave labor in agriculture, began to disrupt and even displace free peasants who streamed into the city of Rome for work; as the population of the city of Rome grew, so did demands for a reliable food supply.[4] The hinterland and adjacent territories of Rome itself were areas where these demands created the greatest impact on agricultural and horticultural transformations in the landscape. This new settlement pattern required a sophisticated regime for the production, storage, and distribution of agricultural products in order to feed the city, often requiring the state to facilitate and maintain this new system.

Ensuring a supply of food was always a critical issue for the Roman state, and numerous attempts were made to provide and guarantee grain for the urban populace.[5]

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[1] Frier 1983, 257n3.

[2] Some notable works include Hopkins 1980; Hin 2013; Morley 2002; Witcher 2005; Scheidel 2004, 2005.

[3] The literature on these estimates is abundant, including Scheidel 2007, 2001; Morley 2013, 1996; Parkin 1992; Hopkins 1978. For a concise summary, see Morley 2013 and Morley 2002, ch. 2, which estimates a population between 850,000 and 1,000,000. Estimates for population are difficult to make, and there have been various approaches, such as from census reports and other documentary sources, especially papyri (Bagnall and Frier 1994; Scheidel 2001; Hermansen 1978), figures of the *annona* recipients in Augustus' *Res Gestae* (Oates 1934) and food supply more broadly (Lo Cascio 1997), and architecture and/or urban layout (Hermansen 1978; Storey 1997).

[4] For discussion regarding these changes in Italy, cf. Morley 1996; Hopkins 1995, 1978 (especially discussion on the agrarian land crisis).

[5] Although the *annona* is associated with the imperial period, there were several important attempts during the Late Republican period on the parts of Gaius Gracchus, Saturninus, and Clodius to address this pressing need. Caesar's and Augustus' reforms obviously made the greatest and most lasting impact. For work on the Roman food trade, especially grain, cf. Rickman 1980; Erdkamp 2005; Sirks 1991; Garnsey 1989, 1999; Aldrete and Mattingly 2000; Vitelli 1980.

Roman conquests enabled the extraction of grain from acquired territories such as Egypt, Sicily, and North Africa, which allowed farmers and landowners in Italy to turn to the more profitable cultivation practices of viticulture and oleoculture.[6] The state furthermore offered numerous incentives to those willing transport grain to Rome, such as tax exemptions, social privileges, and even citizenship.[7] Moreover, institutional developments and technological advances during this period enabled large-scale and long-distance merchant shipments at major ports in the Mediterranean, especially along the west-central coast of Italy.[8] In fact, from the outset of Rome's expansion, the west-central coast of Italy was of prime strategic importance for Rome, and the establishment of Roman colonies at Cosa to the north and Paestum to the south in 273 BCE, as well as the general oversight of the Tiber, should be seen as an attempt to safeguard this vital region.[9] Between the two colonies, a series of ports dotting the coast served Rome's military and economic interests, permitting vast quantities of goods to enter the city. Previous scholarship has probed the effects of Roman conquest on the city of Rome, the urban plebs, and especially the provinces, looking at broader cultural changes that often also touched on the social, economic, and political developments in Italy and the Mediterranean more broadly.[10] Among this growing corpus of work, of course, has also been the focus on Rome's developing food supply system, but a significant question remains: how did the emergence and orchestration of this colossal production and distribution apparatus impact the people living in the shadow of the epicenter of a Mediterranean empire?

This question is difficult. The nature of our evidence privileges the broad mechanisms of the operation and, during the rare instances when people are visible, only the upper echelons of society. As a result, scholarship to date has focused on the Roman state's grain trade (the *annona*), the economic role of imperial estates, and patterns of land use, leaving the people who drove the food supply system largely unnoticed. In contrast, this study turns to the individuals engaged in food storage container industries and agricultural activities, which have been estimated to have occupied anywhere between sixty-five to eighty percent of the total population in antiquity.[11] In pre-industrial societies, the primary and most prevalent economic activities revolved around agriculture, and various studies have explored the

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6 Cf. Purcell 1985 on viticulture in Roman Italy.

7 Cf. Kehoe 2013 for discussion of the role of the state in lowering transaction costs, increasing agricultural productivity, and protecting farmers and landholders.

8 Wilson 2011 attributes the high frequency of long-distance commercial shipping of the Roman period to institutional developments, the eradication of piracy, the use of a single currency, reduced transaction costs, a greater integration of markets, and the consolidation of the Mediterranean Sea under one political entity.

9 Vell. Pat. 1.14; Livy *Epi. Per.* 14.

10 The literature on these topics is vast; some notable studies include Morley 2002 on developments in agriculture and horticulture in Rome and its immediate hinterland; Purcell 1994 on the (lived) experiences of the *plebs urbana*; Witcher 2005 for discussion regarding demographic changes in Roman's immediate hinterland. Work on Roman conquest on various provinces include Millett 1990; Alcock 1993; Woolf 1998; Hingley 2005. For effects of Roman conquest on culture within Italy, cf. Wallace-Hadrill 2008.

11 These figures have been commonly cited by scholars, including Hopkins 1978, 68-69.

production, distribution, and consumption of agricultural products in such societies.[12] Yet the stage between production and consumption — storage — has received far less attention.[13]

Storage of agricultural surplus is of course critical for every society. Communities and households in antiquity processed and stored their foodstuffs in order to access these items of sustenance throughout the year. For communities, the most widely practiced strategy to buffer against periodic variations in food availability, an issue particularly problematic in the Mediterranean was large-scale storage of agricultural surplus.[14] Critical to storage was the proper packaging of commodities in order to contain, protect, identify, and transport them. Storage and packaging were, in other words, the essential stages between production and consumption—where most scholarly attention has been focused—and their infrastructure often required specialized expertise and particular modes of organizing labor.[15]

By examining the practice and the technology of storage and packaging for agricultural products, especially wine and olive oil, that were distributed over increasing distances, this dissertation investigates the effects of Roman imperial expansion on agricultural economies in Italy.[16] It focuses on urban storage practices during the period c. 200 BCE-200 CE, a time during which the city of Rome was becoming the largest and most populated city, and when the Mediterranean was increasingly unified economically and politically.[17] I examine the infrastructure for the technology to store agricultural produce, its packaging and transfer to

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12 Some studies on these topics in the Roman world include Erdkamp 2005; Morley 2002; Garnsey 1988; Bowman and Wilson 2013; Rickman 1980; in the Greek world include Foxhall 1993, Foxhall and Forbes 1982, Halstead and Frederick 2000, Riley 1999, Palmer 2001, van Andel and Runnels 1987, Alcock et al. 1994, Halstead 1987, Wells 1992, Barret and Halstead 2004, Howe 2008. For a diachronic study, cf. Scott 2017. For a recent comparative study of storage in the Andes and Greece, cf. Hastorf and Foxhall 2017.

13 Studies have focused on production, distribution, and consumption, cf. Dietler 2010; Kehoe 2007; Morley 2007; Jongman 2007.

14 For variation in food supply in the Mediterranean region and ways societies responded, see Garnsey 1988, Bintliff 1997, Halstead and O'Shea 1988, Horden and Purcell 2000, ch. 6. There were several possible responses to food scarcity, but the most prevalent included diversification of agricultural products and the production, storage, and redistribution of agricultural surpluses. For agriculture and political economy, see Earle 2002, Smith 2004, Foxhall 1995, D'Altroy et al. 1985, LeVine 1992.

15 Studies have generally focused on production and consumption. For examples in handbooks and collected papers, see Dietler 2010; Kehoe 2007; Jongman 2007.

16 In the history of Mediterranean transport containers, Bevan 2014 states that "the massive expansion of Roman political and economic influence in the last two centuries BC represents an important change in the dynamics of Mediterranean trade and also an opportunity to compare, on the one hand, the large-scale containerized demands of basin-wide empire operating over a coherent fiscal space (at least in principle, and for the only time in the region's history), with on the other, the small-scale but persistent priorities of everyday, regionalized commerce (392ff.)". Tan 2017's study, however, brings to light changes in public finance during the final two centuries BCE, when wealth was already becoming concentrated in the hands of the elites. Nonetheless, the Mediterranean's increasing unity as an economic space offered many trade opportunities.

17 Morley 2002 study of Rome's hinterland during this period synthesized archaeological work to discuss the broad agricultural and horticultural developments to supply Rome.

the consumption site, and its storage prior to secondary distribution.[18] I analyze the character of storage and packaging containers in close detail in order to trace the emergence of new economic structures for their manufacture and distribution and examine how such structures changed over time and how they might relate to other areas of the economy, such as the architectural ceramics industry.

In order to address these and other issues, my dissertation aims to produce a comprehensive study of the main bulk liquid storage container of the Roman period, the dolium, to advance our knowledge of this production, storage, and distribution system and related craft industries. It examines iconographic, documentary, and literary sources with a focus on the various containers utilized for and the actors engaged with the storage and distribution of liquid commodities.[19] Iconographic representations and inscriptions on gravestones, for instance, should some light on who handled these objects and in what way, while agronomists and documentary papyri frequently discuss the organization of labor and industries for this merchandise. Ethnographic studies can also help in conceptualizing the logistical aspects of manufacturing such large vessels. Blitzer's observations of modern-day *pitharia* (contemporary Greek storage containers; *pithoi* in antiquity) production in Messenia, for example, reveal that large *pitharia* required an average of twenty days to form, thirteen to fifteen days to dry, fourteen hours to fire, and five days to cool before they could be removed from the kiln.[20] And of course, the containers themselves also offer evidence as to how they were produced and handled, and occasionally bear stamps and/or *tituli picti* (painted labels) that shed light on the people and industries that used them.[21] For this reason, the empirical core of the project is a direct study of artifactual assemblages from Cosa and Pompeii, two important production centers to the north and south of Rome, respectively, and from Ostia, Rome's port.

The methodology of this project builds upon previous scholarship in three main ways. First, it examines the principal container for storage, the dolium, but considers how it functioned in an ancient Mediterranean system of packaging that also consisted of amphorae, sacks, and skins. Some containers have been featured in various studies, but there has yet to be a comprehensive and systematic overview of containers as a class of materials.[22] Although a wide range of containers were utilized for storage and packaging in antiquity, organic materials rarely survive and are mostly absent in the archaeological record, while ceramic materials are abundant. Examining iconographic, documentary, and literary sources helps balance this perspective by illustrating these containers in their ancient contexts. For example, amphorae are often assigned to specialists whereas dolia are either lumped in with coarse ware pottery or

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18 This will be discussed in greater detail in **Chapter 2.**

19 In addition to material evidence, this project will also examine textual evidence such as papyrological and epigraphic evidence and texts by agronomists such as Cato, Varro, and Columella.

20 Blitzer 1990, 684-698.

21 Dobres 1999 demonstrates how illuminating *chaîne opératoire* can be for how technology intertwines social and material experiences, activities, and identities. See Peña 2007b and Denecker and Vandorpe 2007 for examples of information gleaned from stamps and *tituli picti*. For comprehensive treatment and a corpus of *tituli picti*, cf. Rodríguez Almeida.

22 The only survey is White 1975; containers are often in specialists' studies, ex. Marlière 2002 on *cullei*.

brick and tile materials, with the result that these two groups are often treated separately in excavation reports and publications.[23] In antiquity, however, amphorae and dolia frequently contained the same types of products, and were even occasionally utilized in the same operations.[24] The divergent scholarship on these two types of containers is exacerbated by the uneven treatment of them in publications. Amphorae are plentiful in the archaeological record, and hence also in scholarship, with the result that they are interpreted as an index for long-distance trade. The story for dolia could not be any more different.

Fig. 1.1. Dolium lying on its side (I.22 n. 5), Pompeii.

Dolia were important semi-portable, massive containers that commonly held wine, olive oil, and other foodstuffs at many Roman sites, and determining their presence and abundance could, at the very least, elucidate scales of production and storage (**Fig. 1.1**).[25] Yet strangely no systematic study has been conducted regarding their production, use, or industries.[26] This study makes an advance by utilizing and adapting a comprehensive method

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23 Some projects do not publish their dolium finds. This could be due to the difficulty in identifying dolium fragments (they can easily be mistaken for brick or tile fragments), the lack of a standard study for dolia, and/or the low priority coarseware pottery is delegated for a project's publications.

24 Amphorae are generally associated as transport containers whereas dolia were usually employed for storage and/or fermentation. Shipwreck evidence suggests, however, that dolia and amphorae were both employed as transport containers on certain seaborne vessels. Cf. Heslin 2011; Rice 2016; Marlier and Sibella 2008.

25 Van Oyen 2015's diachronic survey of storage facilities in villas showed that during the first century BCE, storage facilities not only diversified in form, they were also enlarged, monumentalized, and made more visible not only to match increasing scales of production, but also to promote the status of the property owner. Storehouses with dolia were no different and from the first century BCE onwards, these increased significantly in scale as more dolia were packed inside these storage rooms.

26 As recent as Curtis 2015, "a detailed study of dolia remains a significant desideratum" (182).

for documenting artifacts, developed through the Pompeii Artifact Life History Project (PALHIP), to examine over four hundred, mostly unpublished, dolia, dolium fragments, and other similar ceramic storage containers from west-central Italy (**Fig. 1.2**).[27] By elucidating certain stages of the life histories of a large set of dolia, it is possible to identify how different sets of dolia were produced, used, and maintained. In addition, even though this project focuses on Roman sites and material culture, it is informed by research on Greek *pithoi* and ethnographic studies on traditional ceramic storage jars, such as Portuguese *tinajas*, Korean *onggi*, and Georgian *qvevri*, to form a better understanding of large-scale pottery production and logistics.[28]

Fig. 1.2. Evidence for production and repair of dolia from Pompeii, from poster co-presented with Gina Tibbott at the Annual Meeting of the Archaeological Institute of America 2017, in Toronto, Canada.

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27 PALHIP utilizes a detailed FileMaker Pro database the in-depth documentation of artifacts to note evidence for stages of their life history, including production, use-wear alteration, maintenance, repairs, and discards. For more information about PALHIP's methodology and preliminary results, cf. Peña and Cheung 2015; Peña 2014. This will be discussed in further detail in **Chapter 3**.

28 There has been much more work on Greek *pithoi*, cf. Christakis 2005; Blitzer 2009; Giannopoulou 2010.

The second way in which this project aims to advance our knowledge is that it studies and situates the development of these containers within their broader socio-economic contexts to understand not only the development of the craft, but also changes in their industries and organization of labor.[29] Within the archaeological record of the ancient Mediterranean, the Roman period stands out for the proliferation of amphora shapes and for the widespread use of dolia, both suggestive of large-scale production and distribution.[30] These packaging containers were developed to store and transport wine and olive oil, the two major 'cash crops' of the ancient Mediterranean. Consequently, studies have focused on the economic rationale behind modifications to amphora shapes and types, and rarely address the labor and professional organizations associated with these containers.[31] We know, however, that there was a wide variety of occupations associated with Rome's food supply, such as *saccarii* (carriers of sacks of grain), *phalangarii* (carriers of amphorae), *mensores frumentarii* (measurers of grain), *horrearii* (warehouse workers), and *urinatores* (divers to recover goods), among others.[32] Furthermore, there were workshops that produced brick, tile, mortaria, and dolia. There were even specialist dolium potters, probably known as *doliarii*.[33] This investigation of storage and packaging containers therefore also offers the potential to examine these associated industries and their developments within a period of political and economic expansion throughout the Mediterranean.

Lastly, this project will examine the dynamic relationship between two ubiquitous activities normally studied separately, agriculture and craft production, to consider potential cross-craft interactions, such as the sharing of materials, labor, knowledge, and technical expertise.[34] Agricultural products required not only particular processing techniques, but also effective and properly prepared packaging containers, both to prevent spoilage and for distribution.[35] Every agricultural production center, then, no matter how small, needed regular access to adequate storage supplies. Pottery for agricultural commodities could have been produced on the same farm, by a neighboring specialist estate, or procured from independent

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29 Bevan 2014 and Twede 2002, for example, consider the efficiency of amphorae as packaging containers.

30 Bevan 2014, Wilson 2009, Twede 2002 discuss increasing volume to weight ratio for amphoras during the Roman period. Van Oyen 2015's survey of storage facilities found that *cellae vinariae* increased in size and scale in 1st c. BCE.

31 Bevan 2014 in his ambitious *longue durée* study of Mediterranean containers focuses on evolving shapes and types, barely touching upon their social and political contexts. Purcell in his response cautions against the teleological scope of the project and proposes a more focused, comparative approach that would contextualize the history of containers.

32 Cf. Aldrete and Mattingly 2000 for general discussion regarding necessary logistics and general evidence for supplying Rome; cf. Martelli 2013 for representations of *saccarii* from Ostia.

33 *CIL* X 403 from a funerary epitaph is an example of an individual who self-identified as a *doliarius*.

34 Miller 2009 discusses the rich observations made from archaeological studies of socially contextualized technologies. Peña and McCallum 2009A, 2009B and McCallum and Peña 2010 are two rare instances in which scholars have attempted to consider the relationship between local pottery production and agricultural activity in detail.

35 For example, it was necessary to clean (Cato *de Agri Cultura* 152; Columella 12.52.14–15) and resurface the interior walls of dolia with pitch (Columella 12.18.5–7) periodically to prevent spoilage.

potters.[36] Based on maker's stamps and distribution patterns, the dolium industry was highly entangled with the brick and tile industry, which began to proliferate starting in the late Republican period when Roman expansion in west-central Italy was manifested by a high concentration of building projects. In fact, several of the more serious and extensive repairs on dolia drew on methods and materials that were conventional in the realm of architectural stone construction. Who were the individuals who were able to make such repairs? How were they trained? Were potters required to develop their expertise and skills with new or modified storage and packaging containers, or were others now responsible for particular maintenance procedures? Further probing of these types of interactions reveals the connectedness between the various agricultural and craft personnel and how the available packaging types affected the specific modalities for the production and distribution of these agricultural products.

This project therefore not only studies and situates these containers in their various contexts, but also harnesses this material to evaluate the impact of Roman expansion on the individuals who sustained the imperial food supply. It examines three sites of west-central Italy with materials from the second century BCE to the second century CE: two producer sites Cosa and Pompeii, and a consumer site, Ostia (**Fig. 1.3**).[37] As the rest of the study will discuss, the distinctions between production and consumer sites were important for both the development and importance of dolia and their industries.[38] Although dolia were designed as wine production vessels and initially used at production sites in the countryside, they became essential storage equipment and architectural elements in densely populated urban areas, such as Ostia and Rome.

[36] Peacock and Williams 1986.

[37] For overview of the producer city and consumer city debate and dichotomy, and the utility of the consumer city model, cf. Erdkamp 2001.

[38] This stage of the project focuses on dolia from urban contexts, but future work will examine dolia from the countryside to evaluate the relationship between town and country with the focus on food storage.

Fig. 1.3. Map of west-central Italy, with study's three case study sites marked.

The first case study settlement is the town of Cosa, a port colony founded in 273 BCE in southern Tuscany with a thriving wine industry that dominated the western Mediterranean from the mid to late Republic. Hundreds of wine amphorae, originating from Cosa, have been found in large concentration in areas as distant as southern Gaul, testifying to the large-scale wine enterprise there. From the end of the Republic through the imperial period, Cosan products diversified and ranged from wine to fish sauce to various ceramic products, such as lamps, bricks, and tiles.[39] Many of these amphorae and ceramic products bore stamps linked to the prominent Sestius family, offering an opportunity to further explore the developing relationship and (associated) industries for wine, agricultural production, pottery, and other ceramic and terracotta production in this region. Cosa and its hinterland, the *ager Cosanus*, have been the focus of many archaeological projects and studies, and excavations of the town over

[39] Will 1987.

the years have explored the forum, several temples, some houses, and now the bath complex, recovering some dolium fragments in the process. Among the many artifacts recovered from excavations of the town were nearly fifty dolium fragments;[40] though they are low in quantity, mostly from reuse or discard contexts (rather than primary use contexts), and not well-preserved, especially compared to the materials from the other two case study sites, these dolium fragments are among the earliest datable dolia from an urban area.

The second case study settlement, Pompeii, offers a detailed view of storage and packaging during the first c. CE, a period notable for global trade and a 'consumer revolution.'[41] Pompeii, an urban settlement in Campania, was founded sometime in the seventh or sixth c. BCE, and granted colonial status in 80 BCE after Sulla's conquest. Ancient authors noted that Pompeii was particularly fertile thanks to its rich volcanic soil and was hence known as a region that produced plentiful fruits and well-known wine.[42] Archaeological evidence, including architectural remains and archaeobotanical remains, confirms that Pompeii was a productive agricultural town, with farm houses and villas clustered densely not only outside the town, but even within the town walls.[43] Pompeii's state of preservation offers a unique opportunity to study Roman agricultural production and its integration within an urban fabric. The southeastern sector in particular (Regio I and Regio II), which was a green space in the town, along with several 'villas' outside the town walls such as the Villa of the Mysteries and Villa Regina of Boscoreale illuminate the storage and packaging behaviors of Pompeii and the *ager Pompeianus*.[44] There are approximately one hundred dolia and dolium fragments, and another hundred of a different type of ceramic storage jar, mostly found still in their primary use contexts and accessible for study.

The urban populace of Rome was, of course, the major beneficiary of these long-distance movements, and the city's infrastructure was constantly developing in order to facilitate, accommodate, and store the commodities entering the city. The third case study is one of the capital's most crucial ports, Ostia, which shows how the 'local' territory was

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[40] Decades of excavations at Cosa have resulted in various important publications on different finds including thin-walled ware pottery (Marabini Moevs 1973), Italian sigillata pottery (Marabini Moevs 2006), black gloss pottery (Scott 2008), ceramic lamps (Fitch and Goldman 1994), among others. Some dolia were preliminarily published by Dyson 1976, but many remain unpublished.

[41] Wallace-Hadrill 2008 considers the main 'consumer revolution' within Italy to have taken place under Augustus when Italy's population began to recover from civil war, with the result that demands for consumer goods spurred production in Italy itself.

[42] Vesuvian wine was shipped overseas. Thomas 2015; Peña and McCallum 2009a, 2009b have posited that a wine packaging facility would have been located on the coast near Vesuvian settlements and wine production centers.

[43] For discussion and evidence of cultivation in Pompeii in the form of root casts, cf. Jashemski 1979a, 1993.

[44] Cf. Nappo 1997 for discussion regarding urban growth of Pompeii and the reorganization of the southeastern sector of the town. Interestingly, this sector of the town was historically a green space but underwent housing developments during the late 3rd/early 2nd c. BCE. Many of these structures were knocked down to expand the agricultural production and green space of the town during the 1st c. CE.

affected by Rome's own growth from the late first to the beginning of the third century.[45] Ostia underwent further development and several major renovations during the second century CE, when various parts of the settlement, including warehouses, were expanded and/or rebuilt. Among the enhancements in the harbor district were several warehouses containing sunken dolia (*dolia defossa*) to hold wine. Although some of these dolia and their inscriptions, presumably to identify their capacities, have been published, their production, use, and maintenance have not received much attention.[46] This study examines both individual features of the c. 125 dolia still in their primary use contexts and accessible for study and the storerooms as unique sets of storage containers that were produced, maintained, and repaired in a uniform manner in order to illuminate the large-scale enterprise for storing wine to supply the area of the capital.

By uniting a diverse body of published and unpublished archaeological, literary, epigraphic, and papyrological evidence, this study is poised to evaluate the economic and social realities of Roman imperialism on the individuals living in the shadow of the epicenter of a Mediterranean-wide empire through the lens of food storage container industries. It is the first comprehensive study of the ancient Mediterranean's keystone storage container, the dolium. Although dolia never feed into the grand narratives about the Roman economy, they can offer more than just estimates for the economy's scale of production, distribution, and consumption. The dolium is especially informative of the socio-economic conditions, historical features, and cultural preferences of the Mediterranean during the Roman period. Situated at the intersection of pottery, craft production, agriculture, and the construction industry in town, country, ports, and even ships, dolia bring to light interactions and relationships between makers, repairers, and users among seemingly disparate activities. Moreover, they illustrate the interconnectedness and interdependence of a complex system of container industries and storage practices. By studying the nuts and bolts of this commerce, this project opens a new window on a whole series of uncharted interactions in the ancient world. The following chapters demonstrate that the storage and packaging technology so distinctively characteristic of the Roman period was only able to emerge and develop within the particular economic, political, and social climate from c. 200 BCE-200 CE.

Chapter 2 provides an overview of the stages from harvesting to the distribution of wine and olive oil and simultaneously examines the various containers, and their industries, used in these stages. Since containers are usually studied by specialists, they are usually considered in isolation; examining them together, however, reveals how complementary they

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[45] Unlike Rome, Ostia was not continuously inhabited and heavily built over. As a result, the archaeological remains, especially the architecture, at Ostia have been useful in understanding the urban layout and architecture of Rome during the imperial period. For example, both Ostia and Rome had insulae, horrea, and *cellae vinariae* in antiquity, but the examples at Ostia are much better preserved. *Cellae vinariae* and their dolia at Rome were mostly built over or destroyed completely and are known only through inscriptions, with the exception of the Cellae Vinariae Novae et Arruntianae found in the 19th c.; cf. Lanciani 1880; Richardson Jr. 1992, 80 for discussion of various wine storage facilities in Rome.

[46] Peña 2007a is a notable exception and includes observations based on the Ostian dolia to discuss the life cycle (especially production and repair) of dolia as a class of pottery.

were in storing and transporting commodities. The chapter advocates a study of the dolium, the primary storage container for both wine and olive oil.

Chapter 3 traces the emergence and development of the dolium and focuses on the evidence for dolium production, the scale of the industries, and the organization of labor at the various sites. Although dolium producers used the same technique (coil-building), the scale of production differed drastically between the producer sites and the consumer site. By the second century CE, members of the *opus doliare* workshops that produced dolia, bricks, and tile for Rome developed their methods to build massive vessels according to a standardized design; the proliferation and success of these major workshops were so great that the Tiber River Valley had been transformed into antiquity's Ceramic Valley, a hub of ceramic and terracotta production.

Chapter 4 surveys the different types of dolium repairs, some of which were derived from traditional pottery mending techniques while others were entirely new creations inspired by the architectural industries. The types of damage on dolia, and the methods and materials for their repairs, not only shed light on craftspeople's developments in dolium repair technology, but also on the workforce. While more intermittent and general workforces repaired dolia at the producer sites, specialist workforces formed sophisticated and standardized repairs on the dolia at Ostia.

Chapter 5 examines these vessels in their settlements to explore both the relationship between the dolia and the settlement's economic role and scale and how these containers, in turn, shaped the towns. The dolia of the producer sites helped blur the distinction between town and country, by making wine accessible to urban residents. The massive dolia concentrated in four purpose-built storehouses at Ostia, on the other hand, were essential storage equipment that aided rising levels of urbanism in a highly developed and densely occupied settlement.

Chapter 6 considers the factors of the rise and demise of this labor-intensive system for the storage and packaging of wine, and oil to a lesser extent, and traces its trajectory from the late third century BCE to the early third century CE. With a lucrative wine market developing overseas, viticultural areas expanded and the demand for wine and large-scale wine fermentation and storage containers exploded. Potters designed and expanded the dolium, but it was risky and expensive to produce these vessels; dolium production became increasingly subsumed under large *opus doliare* workshops, owned by wealthy aristocrats, senators, and members of the imperial family. There, craftspeople aligned and experimented with their methods, interacting also with the architectural industry to develop new techniques to build these vessels. Over time, a smaller fraction of the Roman elite controlled these large-scale workshops and, as the storage regime for Rome became more sophisticated, the very practices and technologies of storage themselves cast out a wider net that drew in more potters, architectural workers, laborers, farmers, porters, and migrant and seasonal workers to propel and sustain one of the largest agricultural and food systems in the pre-modern world.

Overall, a close examination of dolia in west-central Italy brings to light the ingenuity, cross-craft fertilizations, collaborations, and social and economic constraints of previously unrecognized craftspeople whose remarkable products stored and transported wine across a Mediterranean-wide empire. This study also shows how a food container could inscribe labor practices, social and economic relationships, and industries onto the landscape. But this system of containerization, with the dolium as the keystone container, relied heavily on a widespread abundance of manual labor and natural resources. It was not sustainable over the long term. Sometime in the third century CE, this complex system could no longer be supported, and its demise fostered different modes of trade and ultimately paved the way for a new container system that would be in place for over a millennium.

Chapter 2 Wine and Oil Containers in the Roman World

2.1 ***Introduction.*** Wine and olive oil were the two liquid staple foods of the Mediterranean triad (the third staple was grain). They provided essential nutrients and were used in various aspects of daily life, such as eating and drinking, feasting, religious activity, lighting, and bathing. They could also be stored for long periods of time and transported over great distances, so they were widely traded resources. During the Roman period, these foods were both produced and distributed at increasingly larger scales and over great distances, and have garnered much scholarly interest. Yet the critical stage between production and distribution and consumption – storage – has surprisingly received far less attention.[47] Storage is the process by which commodities are collected and deposited somewhere for preservation towards future use, an essential activity that also prolongs the shelf life of foods and makes them accessible both throughout the year and in times of need, potentially saving households and towns from famine. Closely related to storage is packaging, which is both the process and technology to contain, handle, protect, transport, and even promote goods; food packaging specifically maintained the quality of food for storage, transportation, and eventual consumption, and was a technology practiced at nearly every stage of food processing.[48] Ancient agricultural treatises emphasized the importance and urgency of these processes. Olives, for example, had to be harvested as soon as they were ripening and immediately pressed in order to get the most and best oil. If not, they deteriorated over time and would yield lower-quality oil. But the success of these activities – storage and packaging – depended on containers.

In a world without refrigeration, the containers in which food was stored and transported were vital for a large food supply system. Containers are objects used for or capable of holding something, especially for transport and storage, and will be considered here

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[47] The most well-known and comprehensive study on agricultural storage facilities is Rickman 1971. Since then, there have been studies on storage structures, such as Arce and Goffaux 2011; Escalera et al. 2013; Salido Dominguez 2011; and the École Française de Rome's ongoing excavations at Portus have also shed light on the horrea; cf. Boetto et al. 2010; Keay 2010; Bukowiecki et al. 2008; Bukowiecki et al. 2007; Pagliaro et al. 2014. A few recent studies have begun to examine the social aspects of storage in the Roman world, cf. Van Oyen 2015, but these issues have been explored in political economies of prehistoric societies such as the Bronze Age Aegean and Inka Empire. For Bronze Age Aegean, see papers in Pullen 2010; Forbes and Foxhall 1995; papers in Halstead and O'Shea 1989. For Inka Empire, cf. D'Altroy and Earle 1985; papers in LeVine 1992. Recent work on medieval economies are focusing on food storage, cf. papers in Escalera et al. 2013; papers in Klapste and Sommer 2011.

[48] Han 2005b; Kelsey 1985. Packaging and packaging technology studies are important today as more products are shipped overseas, and there are ongoing attempts to improve packaging efficiency, design, etc. The literature on contemporary packaging is vast, for some basic works cf. Emblem and Emblem 2012; Yam 2009; Soroka 1995. Food packaging is especially important since "most food products deteriorate in quality due to mass transfer phenomena, such as moisture absorption, oxygen invasion, flavor loss, undesirable odor absorption, and the migration of packaging components into the food" (Han 2005b, 4); for studies on food packaging, cf. papers in Han 2005a; Cole and Kirwan 2011.

as the objects used to package goods.[49] Various types of containers were used in antiquity, including baskets, sacks, amphorae, dolia, casks, skins, and glass vessels, to protect, store, and distribute different foods. The importance of these containers in antiquity can hardly be overestimated. They transported olive oil and wine over long distances; often they also served as storage containers; more importantly, though, each container protected its content, ensuring that the product's quality would be preserved throughout its journey.[50] But two important points must be clarified immediately. First, not all containers are created equal.[51] Different types of containers had different properties that made them advantageous or ineffective for particular products, modes of transportation, and/or steps in the process of storage, transport, and distribution. It would not make sense, for example, to package a commodity normally sold in bulk in fragile containers, i.e. shipping grain in glass bottles. Second, containers only functioned as people expected if they were made well and were handled properly before, during, and after each usage. If an amphora had a production defect, it either had to be repaired or replaced to ensure the wine or olive oil could be protected. Properly stoppering and sealing the amphora was therefore an important step before the product could be transported. Moreover, the choice of container was also influenced not only by accessibility and costs of materials, but also by cultural preferences and the availability of types of workforce and industry in the area.

Studying containers and their life histories or trajectories helps us recognize the vast array of craftspeople, skill, manpower, and organization of labor required for making and using these containers; the social and cultural meanings ascribed to them; and their role in

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[49] The definitions of and relationship between containers and packaging are slipper. Klose 2015, ch. 2: containers in shipping systems today are defined as "a means of transport" and are standardized steel boxes associated with maritime transport (46), but the term *container* can mean many different things to different people. Packaging is often considered a process and technology, but also occasionally as the materials used in the process. Klose 2015, ch. 8: today "the development of containers into packaging (and from there into a brand) is mostly a matter of the relationship between objects and their labels" (326) and as a result the terms are often used interchangeably. Here we will consider packaging as a process and technology, and containers the objects employed for packaging.

[50] Recent work on containers have shed light on their importance in shaping the economy; cf. Bevan 2014 for a *longue durée* study of containers used throughout the Mediterranean basin; cf. McCormick 2012 for work on amphorae and barrels. Shipping containers today have tranformed production and consumerism, and various studies have explored on what these containers do, how they transform landscapes and industries, and how they even affect the way we think; cf. George 2013; Levinson 2008; Klose 2015. Interest in containers is growing in different fields. Most recent is a new forum organized by Shryock and Smail (2018) on containers and history that brings together historians, archaeologists, and anthropologists; one of the driving motivations of this forum is that "keeping, storing, holding and pooling are all made possible by a very simple piece of technology: the container" (1) and that "if humans have been co-evolving with containers for millennia, it follows that we, as a species, are engaged in the ongoing experiment of ordering and altering time….[and] the dialectic of containment and exchange" (6). I thank Nicholas Purcell for bringing this timely article to my attention.

[51] Cf. Twede's work on packaging, history of packaging, and packaging performance: Twede 2002a, 2002b, 2005, Twede 2009; Twede and Harte 2011; Twede, Clarke, and Tait 2000a, 2000b.

shaping the economy, labor, and agricultural practices.[52] Chief among storage and packaging containers during the Roman period is a peculiar and understudied vessel known as the dolium, the focus of this study.[53] A dolium was a large ceramic storage vessel that was uniquely placed among different containers, fulfilling special roles that no other container did in antiquity. In order to understand what exactly that role is, and what the potential payoff is from studying it, it will be useful to review the other types of wine and oil containers that operated in the same system.

This chapter first provides an overview of the steps from harvesting grapes and olives to distributing wine and oil to shed light on the various containers that were used in their processing, storage, and transportation in the Mediterranean. Reviewing these types of objects *together* illustrates the interconnectedness and complementary nature of these containers and storage logistics more broadly.[54] Containers functioned in various ways at different stages whether it was to facilitate pressing grapes or protect the quality of wine. The diverse activities to sustain the overall system, which included making, repairing, treating, and properly handling containers and manually transferring their contents from container to container, were labor-intensive and time-consuming. They also drew on different sets of expertise, so examining them reveals the various interactions between various craftspeople and agricultural workers and how agriculture, transportation, consumption, and craft production intersected in antiquity.

52 For benefits of the term 'trajectory' for studying groups of objects, cf. Van Oyen and Pitts 2017, 13ff.: object biographies are useful for studying single objects, trajectories give objects a role to play. Also cf. Joyce 2015; Hodder 2012.

53 Dolia are often published in excavation reports; there have been few attempts to engage with them systematically and comprehensively as a class of materials. Some notable exceptions include Peña 2007a; Brenni 1985; Carrato 2017. Curtis 2015, 2016 discusses them to some extent in considering food storage.

54 Containers are usually studied by specialists. The only survey where different types of containers are treated is found in White 1975, which is a survey of Roman farm equipment and includes materials made of basketry, ceramic, wood, stone, leather, and metal. White collects a variety of textual evidence and summarizes extant archaeological evidence and iconographic representation of these objects, but typically does not discuss the production or industries of these items.

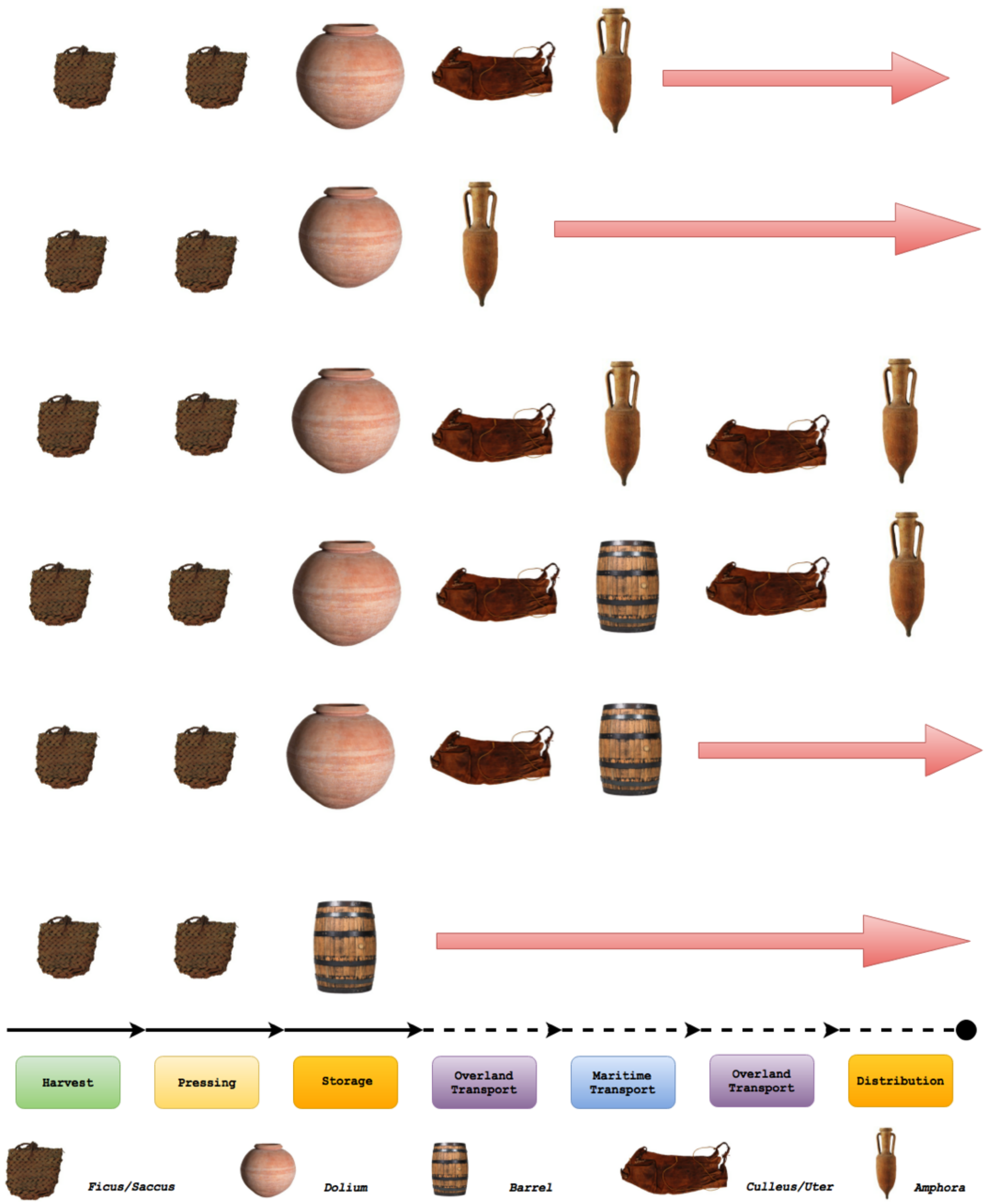

Fig. 2.1. Different possible schemas for the various containers used for the various stages in harvesting, processing, storing, and packaging wine. Barrels will be discussed in **Chapter 6**.

2.2 ***From the Vine to Wine.*** Sometime in early autumn, droves of farmhands, usually contract laborers, freed ripe grapes from the vine, placing them into baskets known as ***fisci*** (**Fig. 2.1**).[55] It was a crucial time. As soon as grapes reached the peak

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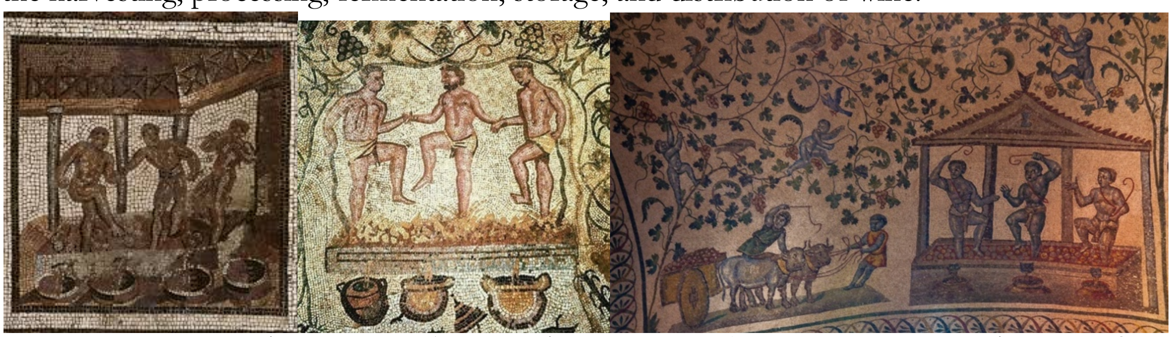
[55] Harvest season for grapes was hectic, requiring huge inputs of labor over a short period of time. Contract laborers were important participants. For corpus of contract work in vineyards, cf. Kloppenborg 2006; for discussion of tenancy and work in Byzantine Egypt on the Apion estate, cf. Hickey 2012, ch. 3.

of ripeness, they were at their sweetest. Workers had to move quickly and harvest the grapes, while taking care not to bruise them or puncture their skins; after gathering the grapes, workers would then tread the grapes in vats and/or press them, often in a bag or sack known as a ***saccus***, and the freshly pressed juice (must) would be collected in large vessels known as ***dolia*** (**Figs. 2.2-4**).[56] During this time, winemakers could employ different sorts of treatments to protect the wine's quality and improve its taste.[57] After at least thirty days of fermentation, the wine was separated from its sediments (lees).[58] The wine was usually sold in bulk by the vintner or, more commonly, to a trader.[59] Workers could then either: (i) transfer the wine into ceramic transport jars known as ***amphorae***, which were often used to export products, especially overseas. Workers could also (ii) transfer the wine first into a skin container known as ***uter*** or an ox hide container known as a ***culleus***, which could then be carted to its final destination, where the wine could be distributed in other vessels for consumption, or to a bottling facility where wine could be poured into ***amphorae*** and shipped overseas.[60] There could have been variations to this schema, but these were the typical stages and containers in the harvesting, processing, fermentation, storage, and distribution of wine.



Figs. 2.2-4. Mosaics depicting workers treading grapes with must collecting in dolia. (L) from Rustic Calendar mosaic at Saint Romain-en-Gal; (C) from House of the Amphitheater, Merida; (R) from Mausoleum of Santa Costanza, Rome.

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[56] This is a simplified account of how wine was produced during the Roman period. There were three batches of wine that were produced: (i) the batch from treading, (ii) the batch from the first pressing, and (iii) the batch from pressing the skins, known as *lor(e)a*, which would be given to slaves for rations. For more detailed discussion, cf. Curtis 2001, 375ff.; Thurmond 2006, ch. 3; for overview of equipment, cf. White 1975. Agronomists occasionally used other terms for baskets and sacks, but *fiscus* and *saccus* were common.

[57] Possible treatments included adding marble or chalk to de-acidify and/or seawater to preserve it.

[58] Cato *de Agri Cultura* 25: wine should ferment for at least thirty days; but Cato and other agronomists do not state a maximum time period for fermentation.

[59] For discussion and evidence for how wine was sold in antiquity, cf. Tchernia 2016, 140-149.

[60] Villa B of Oplontis is a unique example of such a bottling facility that is still preserved. This was a large warehouse, in which was a large courtyard filled with over one thousand amphorae that were previously used and were in the process of being cleaned and filled with wine. They were found stacked upside down in rows along the courtyard near a small furnace in which pine resin could be heated. Since the site was *not* a production facility (there were no vats, presses, dolia, or other equipment, and no sign of vine cultivation such as cultivated vineyards) yet had so many vessels as well as a large entrance for cart traffic, it has been interpreted as a wine bottling facility; cf. Thomas 2015, 2016. For discussion of wine and amphorae production in relation to regional networks in the area, cf. Peña and McCallum 2009a, 2009b.

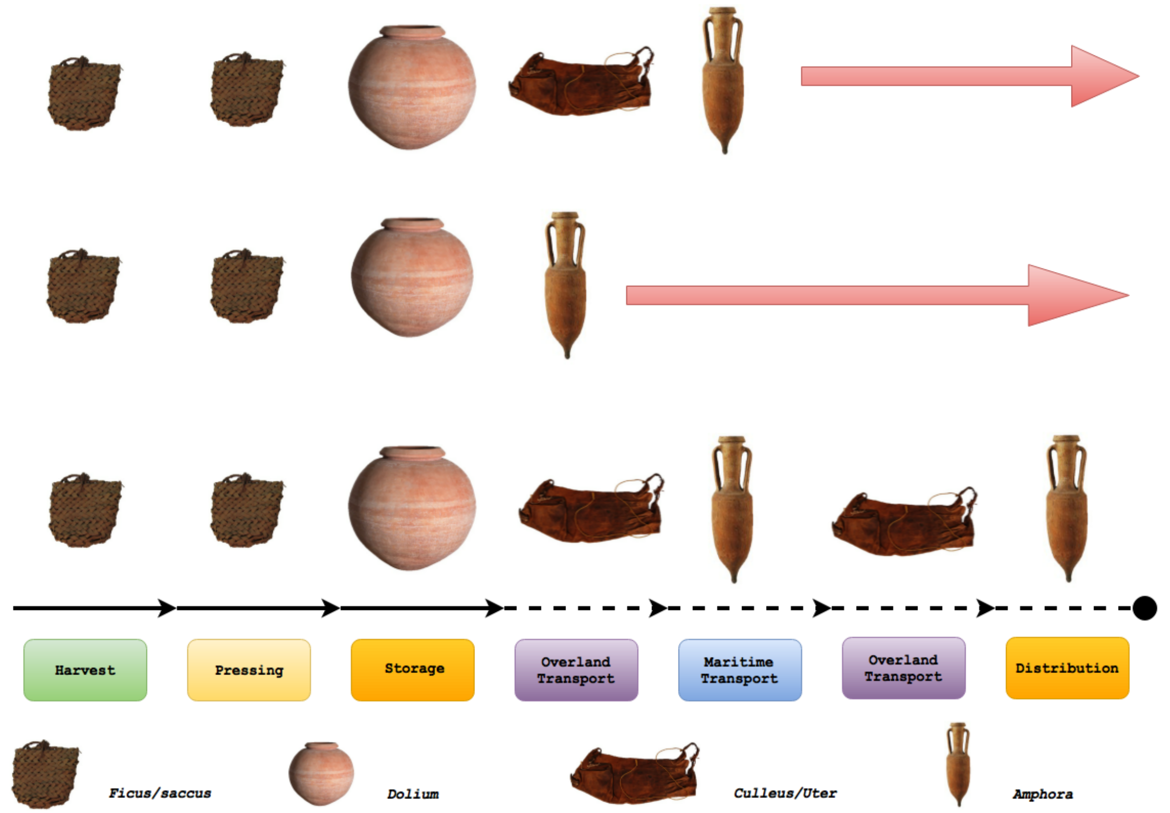

Fig. 2.5. Possible schemas for the various containers used for the various stages in harvesting, processing, storing, and packaging olive oil.

2.3 ***From Olive Fruit to Oil.*** Processing olives was similar to processing grapes, and, in fact, the processes required many of the same equipment, though they usually were not shared at elite production facilities (**Fig. 2.5**).[61] Olives were harvested in late autumn, though there was a wide time frame for when they could be harvested: harvesting less ripe olives at the earlier end of the spectrum would yield high-quality oil, but in smaller quantities, whereas harvesting ripe olives later would maximize quantities of lower-quality oil.[62] After collecting olives in ***fisci*** or ***sacci***, workers had to clean, crush, and press the olives before letting the oil settle. Workers used a *trapetum* to crush the olives, after which they placed the pulp, flesh, and fragmented seeds into ***fisci*** for pressing.[63] After the pressing, workers had to separate the oil from the bitter, aqueous part of the olive, known as *amurca*, which would

[61] The lack of distinction between some of the equipment, especially presses, has posed problems for archaeologists trying to interpret production spaces; cf. Rossiter 1981, Curtis 2001; Marzano 2013. Although processing grapes and olives employed the same presses, at elite sites, the presses were not shared to avoid contamination, and larger, wealthier farms that produced both would usually have two separate areas for the activities. Peasant farms probably did not have separate equipment; for an example of a small press used for both wine and oil production during the 1st c. BCE in central Italy, cf. Vaccaro et al. 2013, 140-142.
[62] This decision was up to the farmer, but Pliny *NH* 18.320 suggested harvesting olives and producing oil right after the vintage. Cf. Thurmond 2006, ch. 2.
[63] For overview of different types of presses used in the Roman world, cf. Curtis 2001, 381ff.

turn the oil rancid if not removed.[64] Workers placed large batches of the oil in a ***dolium*** to settle, and they would later transfer the oil from the ***dolium*** to an ***uter***, ***culleus***, or ***amphora*** for distribution.[65]

2.4 ***Wine and Oil Containers.*** Although making, storing, and distributing wine and oil required similar processes, equipment, and containers, there were several important differences. One was the scale of production. While both products were important components of the Roman diet, processing grapes resulted in much greater yields of wine than making oil.[66] Ancient farmhouses often had several wine ***dolia*** and only one or two oil ***dolia***, and we will see in later chapters that dolia were usually associated with wine.[67] Another distinction was the way, and how frequently, the containers were used, conditioned, maintained, and occasionally reused; someone might have decided to reuse a wine amphora several times, but would throw away an oil jar after a single use. Therefore, although containers rank among some of the most mundane objects from the ancient world, they are the few surviving objects from a world mostly lost to us and are often able to tell us about various cultural preferences and practices. In the following sections I review the evidence for ***fisci***, ***sacci***, ***utres***, ***cullei***, and ***amphorae***, focusing on their production, (re)use, and maintenance and, when possible, the workforces involved (**Table 2.1**); subsequent chapters will discuss the production (**Chapter 3**), repair (**Chapter 4**), and use (**Chapter 5**) of ***dolia***.

2.5 ***Baskets and Sacks.*** Baskets (*fisci*) and sacks (*sacci*) were common farm and transportation equipment and existed in all sizes, from small money-purses to large bags to hold grain or flour (**Figs. 2.6-7**). Although they were important multipurpose and multifunctional containers, sacks and baskets are generally not preserved in the archaeological record, making it difficult to study them; the little that we know mostly comes from textual and visual sources.[68]

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64 Cf. Curtis 2001, 394 for the various techniques of oil separation.

65 Other smaller containers, such as *labra* and *seriae*, were also used for olive oil storage, cf. White 1975.

66 Modern yields estimate that vineyards would yield 1,080-5,000 liters of wine per cultivated acre while olive groves would yield only 450-605 liters of wine per acre. Wine consumption rates were higher though; in Cato's slave rations, they would receive the same amount of oil per month as wine per day. Furthermore, there were different concerns regarding cultivation of vines vs. olive trees: newly planted wines became mature after five years, but olive trees would be mature after at least twenty years, and only had significant olive fruit harvests every other year.

67 Examples include Villa Regina and Villa Pisanella in Boscoreale.

68 A few notable examples include surviving cargo from Camarina B and Valle Ponti/Comacchio shipwrecks. I thank J. Theodore Peña for bringing this to my attention. There are also baskets and other textiles, usually clothing, preserved from Roman Egypt, but attention to and publication of these objects are often sparse and uneven.


Fig. 2.6. (L) Fiber basket from Tebtunis. Hearst Museum at UC Berkeley, inv. no. 6-20555.
Fig. 2.7. (R) Pitched basket made of oak wood and esparto grass, from the Rio Tinto mines possibly to bail water from the underground galleries, from Rio Tinto, Spain, dated to 1st c. BCE-1st c. CE. Madrid, National Archaeological Museum inv. no. 1993/41/1.

Sacks and baskets were used in the harvesting and pressing of grapes and olives, and were commonly listed among pressing equipment.[69] Baskets, typically woven with rushes or linen, could be flexible or rigid.[70] Sacks were made of textiles such as linen and hemp and were probably inexpensive and used for a variety of purposes.[71] Both sacks and baskets were some of the farm equipment that members of the household or farm could produce and repair themselves so they are among the items made on site.[72] Sacks and baskets were used only for short periods of time though, since they offered almost no real protection for their contents. Instead, these were portable and temporary packaging that people, pack animals, wagons, and boats or ships carried to transport goods, such as grain, sets of ceramic vessels or lamps, or other miscellaneous goods for sales.

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69 Cato *de Agri Cultura* 13; 26; 67.2; 68; 153; 135. Cato 26; Columella 12.18.2 advises pitching large amounts of baskets in preparation for a large vintage.

70 Columella 12.52.10, 12.54.2 comments on the utility of *fisci* for pressing olives; Columella 12.39 discusses *fisci* in making raisin wine; 12.38.6 for making myrtle wine. Palladius 4.10.10 in making pomegranate wine.

71 Columella 9.15.12 says they were useful for straining honey (9.15.12) and for making fig vinegar (12.17.2). Pliny *NH* 23.24, 14.28 also describes a *saccus vinarius* used to remove impurities from wine and were sometimes used in spectacles at lavish dinner parties (Petronius *Satyricon* 73). Martial *Epigrams* 14.104 also mentions a *saccus nivarius* that contained snow for cooling wine.

72 Varro 1.22 describes a number of farm equipment that were ideally made on the farm, including items made of hemp, flax, rush, palm fibers, withes, and wood, including cordage, ropes, and mats, and baskets. Cato *de Agri Cultura* 2.3 includes the production and mending of rope and the patching of clothing activities that the household slaves could perform on a rainy day.

Fig. 2.8. Fresco painting depicting the Isis Geminiana ship, from the Ostiense Necropolis along the Via Laurentina, colombarium 31, 1865 excavations, dated to the first half of the 3rd c. CE. Vatican Museums, Cat. 79638.


Fig. 2.9. Marble relief depicting gladiators (first register) and oxen pulling carts of grain sacks (second register), from Magnesian Gate, Anatolia, dated to 1st-2nd c. CE, British Museum no. 1874,0710.324. Courtesy of the Trustees of the British Museum.

Although sacks were used in various activities and for different products, it is worth adding that there was a standardized type of sack for the *annona* (**Figs. 2.8-9**). The Roman state made legal, political, and financial efforts to acquire grain to feed the city of Rome, and large quantities entered Rome through its ports on an annual basis.[73] These *annona* sacks were made to facilitate handling, measuring, and recording, and, when filled, weighed a standard amount that a stevedore could move;[74] their portage was so important that there were workers responsible for carrying these sacks and measuring their contents (**Fig. 2.10**).[75] Grain sacks, though not part of this project, illustrate an important aspect of containers in general: containers were designed and made in ways to facilitate the range of activities in the storage and distribution of their contents, and some of the most widely used and moved containers were entrusted to workers, often of specific occupations.

Fig. 2.10. Terracotta figurine of a *saccarius* from Ostia, from Martelli 2013.

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73 Keenan 2017 argues that a small set of a unique document type preserved on papyrus were 'pricking notes,' which were official records that ship captains or officials pricked as they counted the grain sacks on ships coming into the port of Alexandria. A sophisticated system of testing, unloading, recording, measuring, and storing this grain was in place: the sitologoi and staff, the σιτομετροσακκοφόροι, ensured the quality of the wheat by checking the sealed samples of grain shipments, which were guarded by supercargoes or sample carriers, known as ἐπίπλοοι and δειγμακαταγωγοί; at the port, the *saccarii* carried sacks of grain off ships and boats to warehouses, *mensores frumentarii* measured the grain, and *horrearii* protected the goods and storehouses.

74 Particular workspaces probably made these standardized annona grain sacks, which probably held 3 artabas. Bagnall 2009, 186-187; Mayerson 1998. Duncan-Jones 1976a, 1976b has suggested that an artaba was the equivalent of 3 ⅓ modii xystoi, or 4½ modii italici. Mayerson 1998 suggests that the conversion of the artaba to modii should take into account the customary container associated with the artaba, the sack; Mayerson 1998 suggests that each sack would have contained 3 artabas, or 10 modii, of wheat, weighing under 150 lb.

75 There were workers known as *saccarii*, carriers of grain sacks, at Rome's ports; cf. Martelli 2013 for discussion of terracotta figurines representing *saccarii*. In the papyrological record, there were many words for moving grain, including the σακκοφόρος (sack carrier); σακκοφόριον (the charge for porterage); σιτομετροσακκοφόρος (the one who carried the sacks for the grain measurer); σακκηγία (the transport of sacks); σακκηγός (the transporter of sacks), cf. Mayerson 1998, 190. Cf. Aldrete and Mattingly 2000 for overview of various occupations at Roman ports, including *saccarii* (sack carriers), *mensores frunmentarii* (grain measurers), and *horrearii* (warehouse workers).

2.6 *Skin Containers.* Animal hides were important materials in the ancient world, and some scholars have considered "leather [to be] antiquity's plastic, supplying a versatile, supple, hardwearing, and waterproof material."[76] Although they were widely accessible and used in antiquity, skin containers are rarely preserved.[77] Besides a few key examples, most of what we know comes from textual and iconographic sources and are augmented by ethnographic studies (**Figs. 2.11-12**). A skin container was generally known as an *uter*, while ox hides, known as *cullei*, commonly transported large volumes of liquids. Skin containers are among the most traditional containers for liquids, and making them was an economical and practical way to use the skin of a slaughtered animal.[78] Skin containers came in a range of sizes: they could be made from entire animal hides, and the size of the container would depend on the size of the animal; skin containers could be several small bags cut into the desired sizes from one skin; and there were large, ceremonial containers that consisted of several skins sewn together. In antiquity, people often used goatskins, which provided a mid-sized, personal container that could easily be carried over the shoulder. Cow or ox hide containers, on the other hand, were much larger and held bulk amounts, but transporting them required pack animals or a cart.[79] Due to their porosity, skin containers holding liquids were constantly wet and had the advantage of keeping their contents cool.[80] In addition, skin containers were lightweight yet could hold large amounts of liquids, making them the most efficient containers for liquid commodities in the ancient Mediterranean.[81]

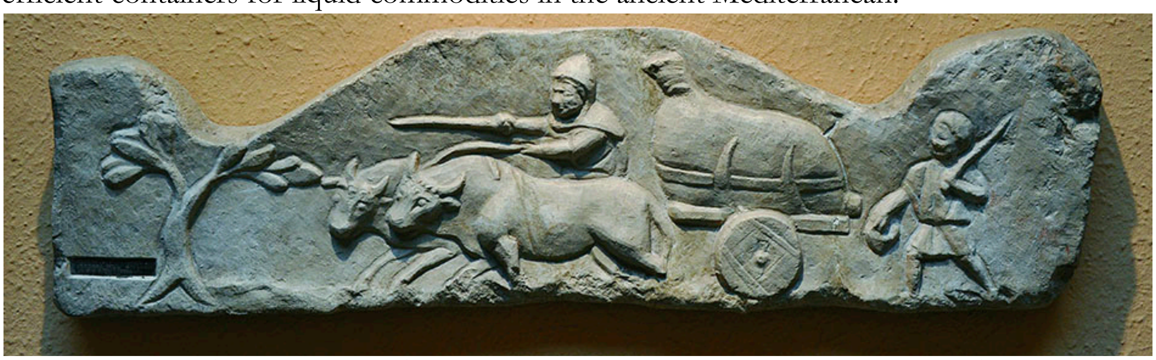

Fig. 2.11. Relief depicting oxen drawing a cart carrying a *culleus*. Rome, Museo della Civiltà Romana. Inv. M.C.R. 3524.

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76 Van Driel-Murray 2008, 481. Animal hides were used for shoes, clothing, harnesses, and tents, but the focus here will be on containers, which were used to hold water and liquid agricultural products.

77 For comprehensive discussion of ancient skin containers (and barrels), cf. Marlière 2002.

78 According to Churchill 1983, it was important to avoid using the hide of animals that had died of natural causes because of the risk of transmitting a disease.

79 Some texts also describe the use of more exotic animals, such as panthers, camels, and rhinoceroses, but only select people used these for special occasions. Callixenus of Rhodes discusses one of Ptolemy Soter's processions in which a large, ceremonial wine skin container, made from skins of several panthers sewn together, carried wine for the festival. See Athenaeus 5.196-203.

80 Borowski 1997, 64.

81 According to Churchill 1983, 64, kid skins weighed 14 oz, doe skins weighed 1.5-2 lb, and billy goat skins weighed 3-5 lb. General estimates assign a weight of 15-20 lb to entire cowhides. This meant that billy goat skin containers had a capacity/weight ratio of c. 3.0 liters/kg and cowhide containers had a capacity/weight ratio of c. 65.0 liters/kg, compared to 0.88 liters/kg ratio for the Dressel 1 amphorae and 1.09-2.04 liters/kg ratio for the Dressel 2-4 amphorae.

Fig. 2.12. Sarcophagus lid depicting a cart transporting wine in a *culleus*, dated to the 3rd c. CE. British Museum no. 1805,0703.458. Courtesy of the Trustees of the British Museum.

Although making skin containers involved more or less the same processes, their production existed at various scales.[82] Skin containers could have been made at home through the more traditional process of curing when individual animals of the flock were slaughtered or, at the other end of the spectrum, through more elaborate tanning processes in workshops that specialized in working with animal hides.[83] Unlike curing, tanning was a complicated and long chemical process that required specific materials and equipment to render the animal hide into a water resistant and longer-lasting material. From as early as the fifth c. BCE, tanning was a specialized craft practiced by *coriarii*, usually men, that took place in structures that were

[82] Churchill 1983, 103ff.; Marlière 2002; Bond 2016, 112ff; Borokowski 1997. The ideal time to skin an animal was in the winter. After skinning the animal, the skin was inverted and then coated or soaked in various substances (salt, flour, urine, or ash) to remove the hair (in the Middle East the skin is buried). The skin was inverted again and the limbs and neck were tied with tar and sewn together to form a handle. Some skin containers also featured a clay pipe inserted into the neck as a spout. Further treatments conditioned the skin and neutralized the taste.

[83] van Driel-Murray 2008, 485: "Two basic forms of skin processing are archaeologically recognizable: curing and tanning. Curing includes relatively simple methods of delaying the onset of decay, by means of smoking or applications of fat or mineral earth. These processes are chemically unstable and reversible, limiting survival. Tanning is a complex process involving infusions of tannins extracted from tree bark or oak galls. The tannins combine permanently with the skin collagen, resulting in a chemically stable product that is water resistant and not susceptible to bacterial decay."

properly equipped with tanning vats.[84] Archaeological evidence of these large workshops has survived at the Roman sites of Pompeii, Vindolanda, Saepinum, Timgad, and Vitudurum. For example, the property in Pompeii, *Regio I, Insula 5*, was specifically designed and used as a workshop for leather working and tanning: it featured an area with tanning vats and an area for multiple drying frames; because tanning leather was a malodorous process, Pompeii's tannery was on the outskirts of the town, just next to the Stabian Gate.[85] Although producing animal-hide containers was originally a rural activity, leather was such an important commodity that it became available in urban workshops and could be widely traded.[86]

While goat hide containers and other *utres* could be personal containers, *cullei* were expensive investments for bulk transport.[87] *Cullei* skin containers could hold a very large volume of liquid (20 amphorae x 26.1 L), yet were both lightweight and flexible. Besides the high cost, the other major disadvantages were the susceptibility to being chewed by rats, insects, and other pests and the inability to stack animal-hide containers on top of one another because they would burst from the excess weight. On the other hand, the flexibility of smaller skin containers made them ideal for transport by cart and pack animals, as they could be secured and fastened to rest against the sides of the animals; but as the skin containers increased in size, their portability diminished and their mobility depended on carts and wagons.

Although they were important farm equipment for holding liquid products, *utres* and *cullei* almost never survive in the archaeological record, with a few exceptions from either extremely arid conditions or waterlogged environments. The expeditions of Nahal Hever in Israel resulted in the discovery of several leather water skins, one of which contained the famous Bar-kochba letters.[88] These water skins were made from the entire skin of a sheep, with the legs tied to form a handle, and were small enough to be a personal container, capable of holding about seven amphorae worth of liquids. Although the containers were made of sheepskin, they were both decorated and repaired with patches of goatskin. Animal hides were versatile and flexible, but also prone to both wear and tear over time and to damage caused by pests, and the Nahal Hever skin containers had been regularly repaired with patches made of other animal hides. In general, this type of maintenance was crucial and might have been frequent enough to have warranted a tanner (*coriarius*) to be on-site where bulk distribution

84 For discussion of the occupation, and associated stigma, of the tanner (*coriarius*), cf. Bond 2016, ch. 3.

85 For discussion of and evidence for fulling, cf. Flohr 2013.

86 The region of Gaul was noted for its superior animal hides, and there was specialized trade in this material with Rome starting in the mid-Republican period, if not earlier, that continued in the imperial period. Pliny *NH* 9.5.14-15: Claudius killed a whale that was feasting on a shipwreck with leather hides from Gaul.

87 Ulp. *Digest* 33.7.12.1 includes *cullei* among pack animals, ships, vehicles, and casks as equipment for exporting produce. Columella 3.3.10 considers the *culleus* to be equal to 20 amphorae or 40 urnae, while Cato stipulates that 41 *urnae* be exchanged for every *culleus* sold. According to Diocletian's *Price Edict*, an ox hide of mediocre quality cost 400 *denarii*, a large goat hide cost 50 *denarii*, a half-liter skin container cost 20 *denarii*, and a skin container for oil cost 100 *denarii*.

88 Yadin 1963.

and packaging took place.[89] Various agricultural treatises and legal texts considered skin containers, especially *cullei*, as the primary packaging container for wine and olive oil from the farm to a bottling facility.[90] Agricultural workers, merchants, and perhaps even specialized transporters known as *utriclarii* transported skin containers filled with wine or oil on pack animals and carts.[91] Although they are almost never preserved, skin containers played a vital role in the chain of packaging for wine and oil during the Roman period.

2.7 ***Amphorae.*** Out of all containers, amphorae (the singular being amphora), are the most well-preserved and have undoubtedly received the most scholarly attention, and will therefore receive the longest treatment in this chapter.[92] Amphorae are double handled ceramic transport containers that were employed for the packaging and distribution of different foods, primarily wine, olive oil, processed fish products, and fruit, throughout the Mediterranean region for centuries.[93] During the Roman period, there was an especially wide range of different amphorae of different shapes and sizes, but the standard wine amphora was one meter tall, weighed over fifty kg when full, and was considered a standard unit of measurement (26.1 liters) (**Figs. 2.13-14**). Amphorae had a distinct, elongated shape, a narrow neck with two handles that connected to the shoulder of the amphora body, and a pointed base that facilitated embedding the vessel into soft ground or in ship hulls.[94] Due to their durability, availability, usability, and relatively low-cost amphorae have been regarded as the characteristic transport container for the ancient Mediterranean.[95]

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89 In Carthage's storehouse, an inscription suggests there could have been a *coriarius* on-site who was responsible for the production and repair of leather packaging (*CIL* VIII, 24654 = AE 1890, 00132). Ostraka from Carthage show that the olive oil packaging was centralized in a state storehouse, and probably transferred from production sites in skin containers to be bottled in amphorae at the storehouse for shipment to Rome. For study on ostraka from Carthage and the packaging of olive oil, cf. Peña 1998. For discussion of skin containers in North Africa, cf. Marlière and Torres Costa 2007.

90 Columella 3.3.10; Cato *de Agri Cultura* 105, 154; Ulp. *Digest* 33.7.12.1.

91 The term *utriclarius* has been found on a number of inscriptions in Gaul, but the precise nature of the occupation is unclear. Some have suggested these were boatmen who used inflated skin containers in transport, referencing a 9th c. BCE relief from Kouyoundjik as evidence. More commonly accepted is that *utricularii* were professionals specialized in the transport of liquid goods in skin containers. Cf. Kneissl 1981; Deman 2002; Marlière 2002, 18ff.; Leveau 2004.

92 The literature on Roman period amphorae is vast. Some notable works include Peacock and Williams 1986; Keay 1984; Gurt i Esparraguera et al. 2005; Bonifay and Tréglia 2007; Menchelli et al. 2010; Demesticha 2015.

93 There are some single handled ceramic vessels considered amphorae, such as the single handled urcei for fish sauce known as the Schoene 6.

94 Amphorae found on the Madrague shipwreck were upright, leaning against each other in the ship hull.

95 Bevan 2014.

Fig. 2.13. (L) Dressel 1B wine amphora made in Cosa, dated to 75 BCE-25 CE. British Museum no. 2006,0331.23. Courtesy of the Trustees of the British Museum.
Fig. 2.14. (R) Dressel 2-4 wine amphora made in Campania, found in Rome, dated to 25 BCE-79 CE. British Museum no. 1756,0101.266.+. Courtesy of the Trustees of the British Museum.

Amphorae have been found throughout the Mediterranean and beyond, both on land and sea, and have generally been used as an index to measure trade and movement of goods in the ancient world. On the other hand, very little survives from the ancient world that tells *how* amphorae were produced and their workshops were organized. Instead, much of what we do know comes primarily from ethnographic studies of traditional amphora production in the Mediterranean. There were several important steps in producing and using an amphora: raw material procurement; paste preparation; forming; drying; firing in the kiln; handling and storage; and treatment of the amphora, such as labeling, closing, and coating the vessel for wine.[96] For the sake of brevity, we shall pay particular attention to workforces and the organization of labor for the following phases: production; treatment; labeling; transportation; and possible reuse.[97]

After potters obtained and prepared clay, they formed amphorae by throwing them in sections and pieces on the wheel, possibly with the aid of tools.[98] Firing amphorae was time-

[96] Peña 2007a, Gallimore 2010.
[97] For discussion of amphora life cycle, cf. Peña 2007a.
[98] For discussion of possible references in papyri, cf. Gallimore, 2010, 168. *P.Tebt.* 2.342.17-19, *BGU* 4.1143.15, *P.Lond.* 3.994.12.

consuming and the riskiest stage of amphora production, and might have been overseen by kiln specialists. Overall, the manufacture of amphorae was a complicated process. Amphora potters tried to produce amphorae with standardized dimensions and capacities;[99] they commonly stamped amphorae with texts and/or pictorial symbols on their handles or necks during production as a guarantee of the container's quality and perhaps the accuracy of its capacity. [100] Manufacturing defects did and were expected to occur, however, and potters had to check for leaks and blemishes.[101] Potters could repair some defected amphorae and probably sold them at a discounted price.

Making amphorae involved more or less the same steps, but amphorae production could have been organized in different ways. Because amphorae were so important for agricultural products, agricultural production facilities, including residences, farmsteads, and large villas or estates, required regular access to these containers. If they had the resources, such as clay beds, fuel, and equipment, agricultural production facilities could have made their own amphorae.[102] Some estates had the resources to specialize in amphora production, and might have operated at a scale large enough to supply even neighboring estates. Not all estates had the resources or labor available to support pottery production though, and some procured amphorae from independent potters, who could have had their own pottery workshops, rented the space and equipment, or worked for the owner of a pottery workshop as a paid worker or as a slave.[103]

After vessels were acquired, there were a number of other important tasks before they were put to use, such as testing them again and treating them.[104] The potters, farmhands, or vintners coated the inner surface of wine amphorae with pine resin, a process known as pitching, to prevent the vessel both from leaking and tainting the wine.[105] After filling the amphorae up to its neck, workers would stopper the amphorae by first placing a plug in the amphora neck to prevent the seal they would later place from contaminating the amphora contents and the amphora contents from weakening the seal (**Fig. 2.15**).[106] Once vintners or

[99] For recent and ongoing work on amphora standardization, cf. Greene and Lawall 2015; van Alfen 2015; Justin Leidwanger's ongoing work on volumetrics and standardization of amphora, including an informal workshop in January 2016.

[100] Scholars have debated whether these stamps identified the manager (*officinator*) of the amphora workshop (Manacorda 1977; Liou and Tchernia 1994); the merchants or farmers who owned the amphorae's contents (Rodriguez 1990); or the manager of the facility that oversaw the filling of the amphorae (Gibbons 2001). Cf. Stone 2009, 130 for discussion of interpretations for stamped amphorae from *Byzacena*.

[101] *P.Oxy*. 3595-7.

[102] Varro *de re rustica* 1.2.22: digging clay pits was considered a reasonable and regular activity on an estate that would benefit the farmer.

[103] For more discussion about the ways amphorae were supplied, cf. Peacock and Williams 1986, ch. 3.

[104] *P.Oxy*. 3354, ll. 16-17: τὴν τῶν χωρούντων εἰ τὸν κατ' ἔτος οἶνον κούφων κομπασίαν ἀφ' οὗ τόπου μεταφέρεται, [we shall] test the jars for the wine each year in the place from which they are transported.

[105] Pliny *NH* 16.21.52. For olive oil, on the other hand, amphorae remained unlined because the oil would have dissolved the pitch and ruined the flavor of the olive oil.

[106] This was one of the important tasks listed in an agricultural agreement, *P.Oxy*. 3354. Cf. Mayerson 2000 for reinterpretation of the term επαλειφω as 'sealing.' Plugs were made from a variety of materials

farmhands properly plugged or stoppered the vessel, they either molded mud-clay or poured plaster or gypsum over the amphora mouth to form a seal to protect the amphora contents and prevent them from leaking and evaporating (**Fig. 2.16**).[107] During the Roman period, there was a range of sealing and materials.[108] After sealing the amphorae, bottlers usually labeled the vessels, and both the mud-clay and plaster seals offered a surface onto which information could be stamped while the seal was wet, or inscribed when dry.

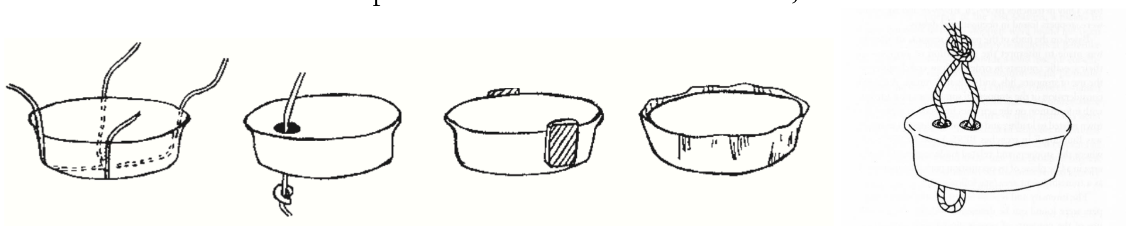

Fig. 2.15. Different types of removal devices for amphora stoppers, after Bos 2000.

Fig. 2.16. Amphora sealants: stamped mud clay amphora sealant, from Mintuoli 2014 (l); stamped plaster amphora sealant, from Thomas 2014 (r).

Labeling amphorae communicated the vessel's contents to the receiver and was an important step before the amphora was transported and distributed. Vintners used stamps to

(cork, wood, pottery, clay, cloth, stone, shell, leather, leaves). Bos and Helms 2000, Figs. 12-14; Thomas 2011, 14; Sundelin 1996, 290-299; Bos 2007, 267: Amphorae were also often equipped with removal devices, such as strings, a central cord, ceramic tabs, or textile, to facilitate the removal of the stopper and opening of the amphora. For various stoppers and their materials, cf. Thomas 2011, 2014; Bos 2007; Mulder 2007; Davoli 2005.

107 Cf. Thomas 2011; Thomas and Tomber 2006; Bos 2007; Mulder 2007; Davoli 2005; Minutoli 2014; O'Connell 2014. The best evidence for this practice come from Egypt, which had a long tradition of using mud-clay to seal vessels.

108 Mud stoppers were often used in Roman Egypt, but primarily at wine-producing estates to pay taxes or for transportation by wine traders for more local or regional trade; since mud-clay deteriorated quickly and easily, it was usually limited to short-term use. Hydraulic pozzolona plaster, which required additional expertise and resources to prepare properly, was durable and waterproof and was the preferred material to seal amphorae for long-distance transportation.

impress often abbreviated information on seals regarding the contents, origins, and ownership.[109] Some Egyptian amphora stoppers have preserved paint on their surfaces, suggesting that vintners color coded seals as part of a system to distinguish the container's contents quickly.[110] Another way to identify the contents of amphorae was by painting commercial inscriptions, known as *tituli picti,* onto the surface of the vessel.[111] This type of labeling proliferated during the second and third c. CE when olive oil became part of the *annona*. Officials and other workers painted the amphorae, eventually dumped at Monte Testaccio in Rome, before and after it was filled with information recording the identity of the commodity, its origin, its weight, and occasionally even the names of the individuals who weighed and documented the oil (**Fig. 2.17**). An uncommon, or at least rarely preserved, method to label amphorae was by tying lead, ceramic, or wooden tags to the amphora handle.[112]

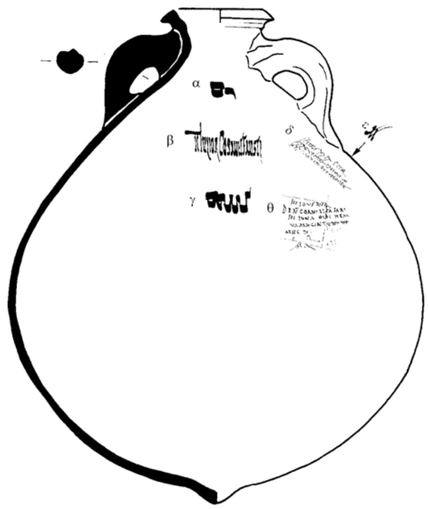

Fig. 2.17. Drawing of Dressel 20 amphora with standard *titulus pictus*, from Aguilera Martín 2012. Alpha = weight of the vessel when empty; beta = name of the shipper; gamma = weight of the vessel and the oil; delta = name of the administrator.

109 Some Egyptian stamps were circular with a Greek name written along the edges surrounding a symbol; the names seem to be of the merchants while the symbol alluded to the origins of the contents. There were also rectangular stamps with texts and/or symbols, some of which contained detailed, but abbreviated, information, while other stamps have abstract texts or symbols that appeared to have been used for branding. For overview of stamped amphora stoppers, cf. Denecker and Vandorpe 2007. For study of rectangular stamps likely used for official purposes, cf. Nachtergael 2000, 2001, 2003.

110 O'Connell 2014: red paint was regularly used on seals for wine amphorae

111 Specific kinds of *tituli picti* on different classes of amphorae recorded particular information, so *tituli picti* on one type of vessel would be unrelated to *tituli picti* on a different type of amphora.

112 For general discussion of amphora labeling, cf. Curtis 2015. For *tituli picti*, cf. Liou 1987; Rodríguez Almeida 1989; Peña 2007a, 99-114. For lead amphora tags, cf. Lequément 1975. Amphorae may have been more often labeled with tags, but tags were either discarded, reused, or did not survive in the archaeological record.

Fig. 2.18. Terracotta figurine of a camel carrying transport amphorae, late 2nd-early 3rd c. CE. The Metropolitan Museum of Art, accession number 89.2.2093.

After labeling the amphorae, farmhands, merchants, porters, and other workers transported them via ships and boats in bulk quantities, or on carts or pack animals in small numbers (**Fig. 2.18**).[113] For the transport of amphorae, it was imperative to have a steady workforce ready to move these vessels, whether it was on and off ships by hand or by crane, onto carts, into a warehouse, or to an administrative station (**Fig. 2.19**).[114] Amphora carriers, known as *phalangarii*, constituted an essential workforce at the ports of Rome. They carried amphorae on and off ships, and transferred them between larger seafaring ships and smaller riverine boats. During the late Roman period, this concern became even more pressing with African oil amphorae, which could contain twice the amount other amphorae held. For large amphorae, at least two people carried them, probably by hoisting a pole on their shoulders that looped through the handles of the amphora (**Fig. 2.20**).[115]

113 For overview of iconographical evidence of amphorae handling and transportation, cf. Lund 2011.
114 For general discussion regarding ergonomics of amphorae and amphora handling, cf. McCormick 2012. For overview of cranes in loading and unloading ships, cf. Wilson 2011, 51; Wilson 2008, 342-344; Rougé 1966, 160-166; Casson, 1971, 369-370. Vitruvius *de Architectura* 10.2.10.
115 Vitruvius 10.3.7: groups of four to six *phalangarii* would distribute the weight of extremely large loads evenly across their carrying poles so the load would not slip out of place.

Fig. 2.19. (L) Relief depicting porters carrying amphorae off ship. Rome, Capitoline Museum.
Fig. 2.20. (R) Relief depicting workers carrying amphorae with a pole, displayed at Pompeii.

After acquiring amphorae and emptying them of their contents, amphorae users often discarded the vessel, but sometimes they did not.[116] Only more recently have studies shown that people in antiquity reused amphorae more often than we had thought.[117] Scholars have traditionally assumed that specific classes of amphorae tended to be employed by and large for the packaging of one specific kind of content; as a result, some of these amphora types have been erroneously assumed to have held only certain products.[118] More recent scientific analyses have shown that amphorae often contained different types of contents, many of which were not wine, oil, or fish products.[119] In some instances, people reused amphorae to hold the same type of content as its first use; wine amphorae were often reused, and could be reused multiple times, to hold new batches of wine.[120] But not all amphorae were reused equally. The selection of amphorae for reuse depended on the ability to acquire and re-treat them, such as cleaning, modifying, and (re)pitching the vessel. Amphorae that held oil and fish products were only occasionally reused for the packaging of other foods, such as cabbage.[121]

116 There were common practices in purchasing an amphora of goods, including a *degustatio*, cf. Frier 1983.

117 For overview of amphora reuse, cf. Peña 2007a, 61-118; Peña forthcoming. I thank J. Theodore Peña for sharing an advance copy of the manuscript.

118 Bonifay 2004's synthesis on African amphorae has seriously challenged the view that African amphorae held solely olive oil.

119 They include the detailed analysis of preserved macro-remains recovered inside amphorae from shipwreck sites and the analysis of absorbed residues in amphorae. A recent conference on amphora contents in Cadiz in September 2015 and its forthcoming publication discuss many new findings.

120 Cf. Pecci et al. 2017 for analysis of wine amphorae reused to hold new batches of wine. Thomas 2015, 2016; Muslin 2016: excavations of Villa B at Oplontis uncovered over a thousand previously used Dressel 2-4 amphorae were cleaned and relined with pitch to export wine overseas.

121 Pliny *NH* 19.41.142; discussion in Peña 2007a, 117-118. *P.Fay.* 117 is an early second c. CE letter in which the father, Lucius Bellenus Gemellus, entreats his son to send different foods, including five unknown units of cabbage; perhaps they were placed in sealed jars.

They were particularly ill suited for reuse as packaging because the substances were often absorbed into the vessel walls and could not be fully removed. Because oil and fish sauce amphorae often went rancid after the first use, they were instead commonly reused as construction materials for construction.[122]

Given the potential utility and value of used amphorae and the necessary work for acquiring and preparing them for reuse, commerce and services associated with this was probably prevalent in antiquity. In fact, an epitaph tells us that a certain Gaius Comissius Sucessus, who was a *negotians Porto Vinario lagonaris* in the wine-trading district of Rome, probably earned his living by collecting, cleaning, and treating wine amphorae that had been emptied and then selling them to people who needed containers to haul wine they just purchased (*CIL* 6.37807).[123] Overall, the production, use, handling, distribution, and even reuse of amphorae relied on many workforces to ensure the availability and proper handling of these transport jars.

2.8 ***Conclusion*** Containers were some of the most essential objects and actors in an intricate system of storage and packaging that made food available yearlong and in far-flung destinations, one of the most remarkable traits of the Roman Empire. Yet containers are mundane objects.[124] In fact, they are so mundane, that their potential has often been overlooked. When they are studied, they are interpreted in a straight-forward manner as proxy evidence for other phenomena, such production and trade. But containers are the products of the traditions and behaviors of storage and packaging, and they reflect some of the deepest cultural mentalities and preferences. The availability of certain container types not only depended on the availability of natural resources, but also on the cultural preferences, the social context for the organization of labor, and economic conditions. Agricultural workers expected to use specific types of equipment and containers in processing and packaging their goods. Wine was supposed to have a particular taste and texture, and it was supposed to be packaged, presented, and labeled a certain way.

This chapter has provided a brief overview of the various containers used for the processing, packaging, and transport of wine and oil in the Roman world. As the discussion has highlighted, these containers were necessary for the proper handling, preservation, and transportation of commodities in the ancient world, and were designed and developed to protect and communicate their contents throughout storage, record-keeping, measuring, shipment, overland transport, counting, and sampling. What is less readily visible, yet no less important, is the industry of these containers. Containers are only the few surviving objects of a complicated and peopled industry that was embedded in its contemporary social, economic, and political environment, of which very little remains. The containers preserved in the

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122 Lancaster 2004, ch. 4: repurposing of amphora in vaulting was part of a tradition whereby amphorae were repurposed in land reclamation activities and then concrete construction both to repurpose ceramic vessels that would have otherwise been discarded and to save on construction materials and manpower.

123 For discussion of epitaph and interpretation of *lagonaris*, cf. Peña 2007a, 115ff.

124 For value of objects, and how that can change over time and in different cultural contexts, cf. Appadurai 1986; Kopytoff 1986.

archaeological record and recorded in texts were ultimately made possible by the producers', merchants', and consumers' choices and abilities to utilize and develop certain containers. When examined closely, the containers also bear information on how they were handled, not only in their production, but also in their transport of goods, bringing to light the activities, organization of labor, and movements of the people who were entrusted with this responsibility.

Surveying the different types of containers used for wine and oil in the Roman period has also highlighted how labor intensive the whole process was. The ancient Mediterranean packaging system required different kinds of containers throughout the process, many of which had to be used, treated, and maintained in distinct ways and sometimes on a regular basis. Farmhands had to clean, mend, and condition containers and other farm equipment throughout the year, while there seems to have been designated occupations for collecting and treating used amphorae and transporting skin containers. Not only was this packaging system demanding for farmers and container producers and repairers, but it was also onerous for the porters and transporters who had to do the heavy lifting. Furthermore, unlike today's system of containerization, in which goods are moved in intermodal shipping containers (standardized steel boxes designed to be used across different modes of transport so their cargo does not have to be loaded and unloaded each time), wine and oil in antiquity had to be transferred from container to container at *every* stage, often manually (**Figs. 2.21-22**).[125] To ladle several hundred liters of oil from a dolium into amphorae was probably the work of a poor slave or contract worker, whose cheap labor made Rome's food supply system possible.

Fig. 2.21. Relief panel from the lid of a marble sarcophagus, showing the reduction by boiling of *mustum* (newly pressed wine) to *defrutum* (a thicker brew). British Museum no. 1805,0703.457. Courtesy of the Trustees of the British Museum.

[125] Siphons and pumps were probably available at some sites, but ladling was often expected. Cf. Cato *de Agri Cultura* 66 in which he advises placing a ladler (*capulator*) in the press room to skim off the amurca with a ladle; Columella 12.52.8-12.

Fig. 2.22. Sampling and sale of wine from the *cella vinaria*. In the center, workers ladle out wine into an amphora. Stone relief from Ince Blundell Hall, Liverpool World Museum.

The discussion has also addressed the complementary nature of storage and packaging containers in antiquity. No container was perfect. In the ancient world, people had the option to select from various types of containers for the different activities in storing and transporting a wide range of commodities. Although amphorae are the best-preserved containers in the archaeological record, and hence rank among the most studied objects, they were not ideal containers for bulk land transportation.[126] They were well suited for overseas transport, positioned upright and leaning against one another aboard ships. Amphorae transported in carts were susceptible to being damaged, especially if roads were uneven or difficult to access, while the best-suited container for bulk land transport of liquid commodities was the skin container. Ultimately, no container could do it all. Different containers were used, and necessary, for the various stages of harvesting, processing, storing, and distribution of wine or oil. Farmhands harvested grapes and placed them in baskets; after they were pressed, they stored the wine in a dolium; if the landowner, manager, or merchant wished to transport the wine in bulk, they transferred it from the dolium into a skin container; for overseas transport, the skin container would be carted into a coastal packaging facility,

126 Amphorae were transported in carts or on pack animals for overland transportation, but not in bulk quantities.

where workers would transfer the wine from the skin container into amphorae, which they would then load onto ships to be delivered farther afield. The complex storage and packaging apparatus in the ancient world was made possible by an interdependent and interlinked network of containers that required a great deal of labor.

For this reason, studying the food supply by looking at only one type of container in isolation gives only a small piece of the puzzle. Looking only at amphorae from a site gives a sense of some of the goods that were brought in, but those amphorae are only the containers that were able to reach the site and remain there to be discovered later. If we want to have a fuller understanding of the various industries, workforces, and cultural forces at work for the food supply system, we need to approach the entire system of packaging, starting by focusing on the crucial, yet overlooked, stage of storage. Throughout this chapter, we have looked at the stages and containers for production and distribution, but the stage in which wine and oil probably spent the most time in was storage, in the container known as the dolium.[127] Unlike most of the other understudied containers this chapter has discussed, namely sacks, baskets, and skin containers, dolia can be well-preserved, and are found in large numbers throughout the Mediterranean. There are about two hundred dolia at the site of Ostia alone, and hundreds of dolia and other similar large ceramic storage jars in the Vesuvian region. The following chapters demonstrate how studying dolia sheds light not only on the growth of the food supply and its associated craft industries in the Roman period, but also how it happened and how it shaped the Roman economy and landscape of west-central Italy.

[127] Cato *de Agri Cultura* 3 advises the reader to have enough dolia at the farm to store wine and oil and wait for prices to raise before selling.

Chapter 3 Building Big: The Construction and Production of Dolia

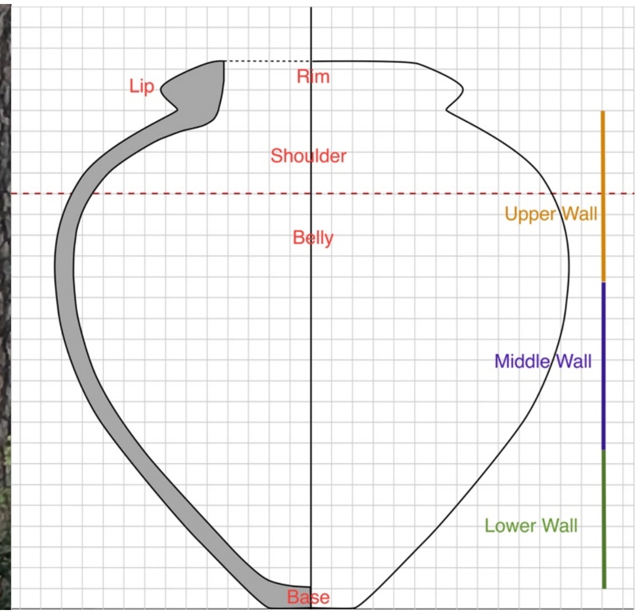

Fig. 3.1. (L) Dolium on a pedestal at Villa Celimontana in Rome, now used for decoration.
Fig. 3.2. (R) Terms used to describe dolium, adapted from profile drawing by Gina Tibbott.

3.1 ***Introduction.*** Dolia (the singular being *dolium*) were large ceramic storage containers that were primarily used to hold wine, though they also stored other foods, such as oil, grain, and fish sauce (**Figs. 3.1-2**).[128] *Dolia defossa*, dolia buried to their shoulders, have been found in houses, farms, warehouses, and port facilities. But they have also been placed on ships, secured or cemented into the hulls (**Fig. 3.3**).[129] Because they were such important storage vessels, dolia can be found throughout the Roman world, multiple complete sets of dolia can still be found in-situ, thus providing direct evidence about how people in antiquity stored different foods (**Figs. 3.4-5**).[130]

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128 Dolia and other large ceramic storage containers were also used for water storage, raising dormice, or for food processing such as pickling turnips or producing fish sauce.

129 Dolia were found cemented in the hull of ships dated from late 2nd c. BCE through 1st c. CE, generally surrounded by more wine packaged in amphorae. The concentration of these shipwrecks, and the peculiar nature of these ships, suggest that these ships were specially designed to transport wine. These ships were small and low (18-22m x 6-7m), allowing them to sail in both the sea and rivers. Based on stamps found on dolia on these ships, the dolia, and probably the ships too, originated from Minturnae and were produced by three or four generations of the Piranus family as a concerted effort to transport bulk quantities of wine on seas and rivers. Cf. Marlier and Sibella 2008; Heslin 2011; Rice 2016.

130 The best examples are buried dolia (*dolia defossa*) in the wine cellars (*cella vinaria*) in farmhouses in the Vesuvian region and the warehouses at Ostia. There are some also found in wine production facilities in other parts of Italy, but those are usually not as well preserved. The eruption of Vesuvius in 79 CE meant that many of the dolia in the region were preserved in-situ and during their last phase of use. There are also dolia found in-situ in warehouses in southern Gaul.

Fig. 3.3. Reconstructed model of specialized wine dolium ships, by the Centre National de la Recerche Scientifique, Centre Camille Jullian.

Fig. 3.4. *Dolia defossa* in *cella vinaria* at Villa Regina in Boscoreale, from www.boscorealecultura.com.


Fig. 3.5. *Dolia defossa* in Caseggiato dei Doli, Ostia.

Dolia had a capacity between 200 to 3,000 liters. This makes them by far the largest vessels in antiquity. With their cumbersome shape and size, they were not considered *portable* material culture, and moved only when necessary: from production facility to place of use and then again if they changed owners.[131] (Moving a large dolium called for the help of several people.)[132] Although they were considered a class of pottery, they were produced alongside brick and tile products in the same workshops that supplied the building industry of Rome. And the law classified them as fixed architectural elements of a property, and the defining feature of a wine cellar. Dolia, considered both ceramic containers and architectural elements, bring together various aspects of society normally studied separately in scholarship: pottery, agriculture, construction and architecture, and craft production.

131 There is archaeological evidence throughout the Vesuvian area that dolia were removed (Villa of N. Popidi Narcissi Maioris, cf. De Spagnolis 1991-1992; Pompeii I.22, cf. Cheung and Tibbott forthcoming; also at Villa Magna, cf. Fentress et al. 2017); they could have been acquired as secondhand farm equipment or robbed from properties. In Apuleius *Metamorphoses* IX.5-7, a couple agrees to sell their old dolium for a few *denarii*.

132 A qvevri (Georgian wine vessel similar to dolia) maker says it takes eight men to move one qvevri. http://www.winenous.co.uk/wp/archives/10018

Despite their widespread distribution and importance, systematic studies of dolia have not been conducted due to lack of scholarly interest.[133] The lack of interest is only further compounded by difficulty in studying them: dolia were often buried or are poorly preserved. Archaeologists commonly misidentify fragmentary dolia they recover as bricks or tiles during the excavation process, and the pieces are either thrown away or condemned to the purgatory of non-inventoried artifacts. Those that are recognizable are usually buried in the ground or embedded in an architectural feature, making it impossible to get even a full view of the vessel. This starts as early as in the excavation or survey phase of an archaeological project: because of the similarity in their ceramic fabric (the characteristics of pottery's clay body), it can be difficult to distinguish a fragment of dolium from a fragment of brick or tile, so often dolia are not even properly identified.[134] But even when they are properly identified, there are other challenges. Unlike fineware pottery, which changes rapidly over time for developing tastes and preferences, dolia were utilitarian vessels that mostly remained unchanged, so they are impossible to date precisely based on form alone. When dolia are studied, they are usually used to gauge the scale of production or trade in a preliminary manner.[135]

While dolia are rarely considered participants in the ancient Mediterranean economy, this chapter argues that dolia can be informative in multiple ways. At the very least, these vessels can underpin our estimates of the scale of production, distribution, and consumption of foodstuffs, particularly wine and olive oil, in the ancient world. The emergence and growing numbers of dolia throughout central Italy and the entire Mediterranean demonstrates a changing scale of the economy and of the wine industry in particular. While amphorae and their movements have been studied to gauge the scale and expansion of the Roman wine trade, dolia and the potential insights they offer on wine production and storage, which speaks to both exported and local consumption (unlike amphorae), have been overlooked. Dolia can also feed into a different narrative, each vessel with a story of its own to tell. To the trained eye the physical conditions of the vessel reads like a history of its interactions, shedding light also on the persons who came into contact with them. Taken together, these massive containers advance our understanding of craft production, industries, technological skill and knowledge, economic activities, and labor in antiquity. This chapter shows that dolia from urban settlements in west-central Italy over the course of approximately four hundred years were products of a developing ceramic craft, which specialist potters established and continuously refined; dolium production was so complex, risky, and expensive, yet potentially

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133 Brenni 1985, an MA thesis, is a comprehensive study that cataloged all published dolia. Carrato 2017 is a recent comprehensive study on dolia in Gallia Narbonensis from 1st c. BCE to 3rd c. CE; Salido Domínguez 2017 is a recent overview of dolia in Spain.

134 For definition of and description of analysis of ceramic fabric, cf. Orton and Hughes 1993, ch. 5. The similarity between the fabrics of bricks, tiles, and dolia suggests these objects were produced in the same workshops; cf. . Although bricks were humble objects that are often simply counted and weighed, their stamps contribute to the writing of social history and have thus been studied in detail; cf. Steinby 1998.

135 For the Villa Regina at Boscoreale, De Caro 1994, 63-69 estimated how much wine was being produced annually, and hence the size of the vineyard, based on the *dolia defossa* in the *cella vinaria*. Heslin 2011; Rice 2016 have interpreted dolium shipwrecks as intensive efforts to ship bulk quantities of wine.

profitable, it became part of a different, and stable, craft's enterprise that eventually dominated the Tiber River Valley: the architectural ceramic industry. As these large ceramic and terracotta (*opus doliare*) workshops invested more in dolium production, the smaller pottery workshops that manufactured dolia in earlier periods began to fade away; the organization of labor for these crafts changed over time and large *opus doliare* workshops, which came to monopolize dolium production, offered dolium makers a range of resources to refine a lucrative wine vessel, including space, equipment, materials, and, most importantly, sufficient capital for investment and innovation.

3.2 ***Tracing the Dolium's Origins and Development.*** Since there has not been any comprehensive study of dolia, there has not been even a general consensus on what a dolium is. The term *dolium* is casually employed to describe any giant jar that is not easily identified as a more familiar type of pottery. As a result, the dolium is often considered a large multipurpose vessel used for storing different foods, but it was actually a *multifunctional* vessel with a design for a primary purpose: wine fermentation.[136] In antiquity, the term *dolium* was used for a specific type of large ceramic storage vessel that was commonly used to hold wine or, less frequently, other goods such as oil and grain.[137] Although *pithos*, the Greek equivalent of the word *dolium*, was used early on in the Greek speaking world to describe a similar type of large ceramic storage container, the usage of the word *dolium* came much later, appearing for the first time in Plautus' *Pseudolus* and Cato's *de Agri Cultura*.[138] Yet Varro tells us that, before *dolium*, there existed an ancient word, *calpar*, a vessel which was specifically associated with wine; *calpar* came from the Greek word *kalpis*, which was a term for a specific wine vessel and also meant "new wine," because the vessel's primary function was to hold sacrificial wine.[139] A dolium was originally and commonly associated with wine not only linguistically, but also morphologically. In antiquity, dolia were expected to have wide shoulders and a strawberry

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136 For recent work drawing on design theory in Roman material culture studies, and how *affordances* can bring to light objects' 'proper' and 'system' functions—how they were supposed to be used vs. how they were used—and the relationship between the two, cf. Swift 2017a, 2017b. I argue that dolia's proper function was wine fermentation, but their system function came to include storage for many different foods and miscellaneous things.

137 For a succinct discussion of textual evidence for dolia, cf. White 1975, 145ff. Iul. *Dig.* 50.16.206 classifies a dolium (and a *seria*) as wine containers that, when not in use for wine, can hold other goods.

138 Pithoi have been used for several centuries to describe a large ceramic storage container, which can be found in Bronze Age palaces for example. *Pithos* seems to have been a general storage container, commonly used to hold grain or oil, but did not seem to have been strictly associated with any particular content. Plautus *Pseudolus* 1, 3, 135: *ingerere aliquid in pertusum dolium* ("to put load something into a perforated dolium") meant to waste one's effort or to labor in vain. By the early second c. BCE, then, the dolium was well-known enough in the cultural imagination and day-to-day vocabulary that one could speak about them proverbially. I thank Kevin Moch for bringing this to my attention. Some scholars have hypothesized that a fragment of Ennius (Fest. 278) includes *pertusum dolium*, but the reading is too tentative to be certain. Regardless, *dolium* seems to have been well established by the early second century.

139 *Thesaurus Linguae Latinae* entries on *dolium* and its synonym *calpar*; Varro frg. Non. p. 547. I thank again Kevin Moch for bringing this to my attention.

shape in order to accommodate the expansion of gas during the fermentation process;[140] the dolium's morphology and material must have given its wine a particular taste and texture that Romans were accustomed to and preferred.[141] (In fact, vintners today employing a similar fermentation vessel, commonly referred to as an egg, extol the design because it provides a thermally stable environment for biodynamic fermentation that eliminates the need for stirring, resulting in a more even, flavorful wine.) Although dolia varied in size, their average size was large, capable of holding approximately one to one and a half *cullei* (c. 550-750 liters).[142]

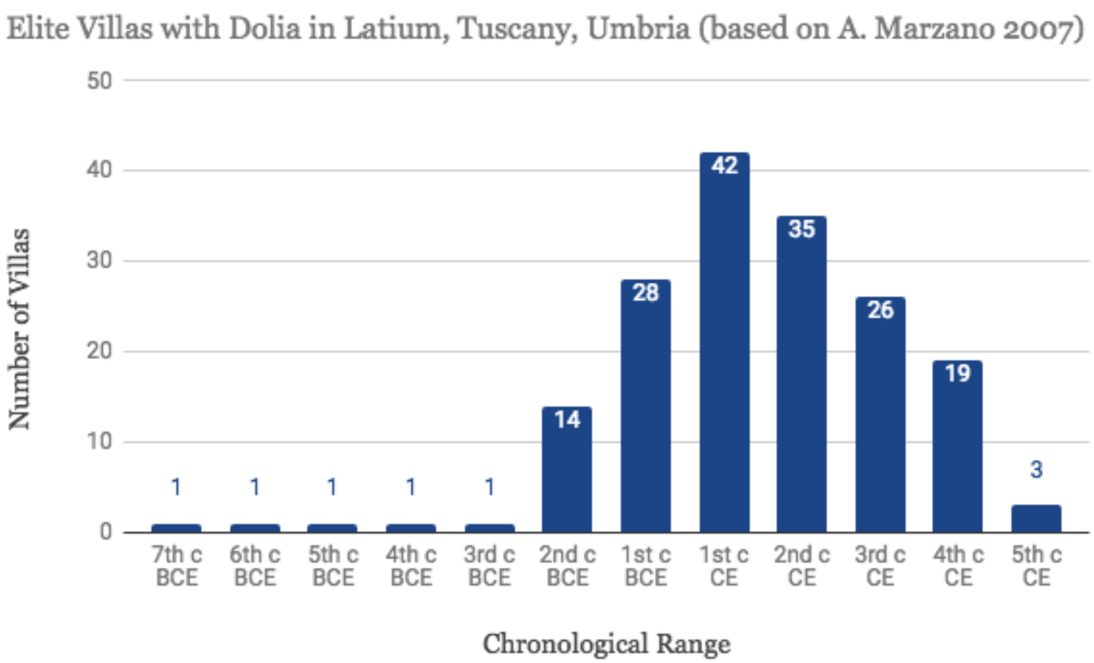


Figure 3.6. Chronological Range of Elite Villas with Dolia in Latium, Tuscany, and Umbria, based on Marzano 2007. Uncertain whether there were dolia predating the 2nd c. BCE.

140 Columella 12.44.2 discusses pickling jars and says they must have straight sides and profile, unlike dolia.
141 Pliny *NH* 14.27 on the different taste of wine made in barrels.
142 Diocletian's Price Edict 15.97 gives the price for a 550-liter dolium. Columella 12.18.7 advises using 25 lb of pitch to coat the walls of a 750-liter dolium.

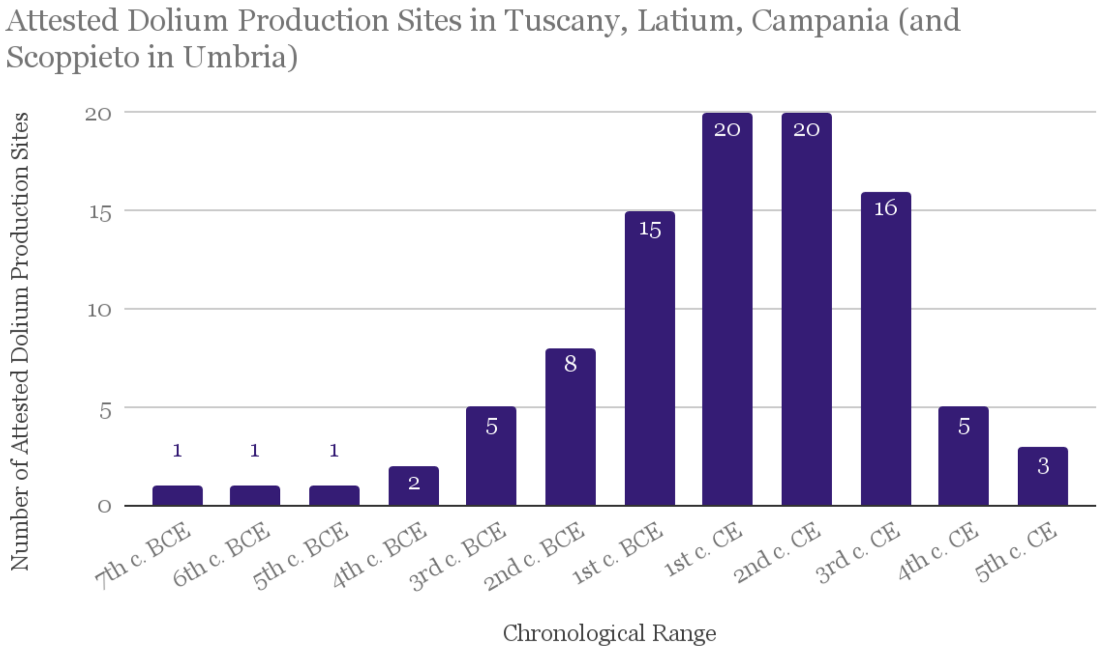


Fig. 3.7. Chronological range of attested dolium production sites in Tuscany, Latium, and Campania mostly based on data from Olcese; includes Tol and Borger 2016's study of ceramic production on the Pontine Plain and Bergamini 2008's study of ceramic production at Scoppieto in Umbria.

In addition to the textual evidence, the archaeological evidence also suggests that the dolium did not become the established wine container until sometime in the third century BCE. Based on a survey of elite villas in Latium, Tuscany, and Umbria, villas with dolia did not appear in significant numbers until the second century BCE (**Fig. 3.6**).[143] The earliest preserved dolium could be the dolium rim fragment found at the Auditorium Villa in Rome, dated to the late fourth or early third century BCE, or dolium rim fragments from the mid third century BCE found at Ostia, but even those identifications are tentative.[144] Large-scale ceramic storage vessels certainly existed earlier, but associating them with dolia is difficult. *Pithoi* and other similar vessels are found in great numbers throughout the Mediterranean, but these vessels had a more cylindrical morphology, primarily stored cereals and oil, were usually

143 Marzano 2007 primarily studied the Roman elite villas in Latium, Umbria, and Tuscany. Dolia were not central to the study, but Marzano's catalog helpfully indicated when dolia were found and recorded. The single dolium from the Iron Age has not been confirmed as a dolium (the original publication included no photographs or drawings). But because Marzano's survey draws on many poorly villas, future work of this project will survey additional materials, especially non-elite producer sites.

144 Carandini 2006; Olcese and Coletti 2016, 455-456. Even these identifications are not secure since only the rim has been preserved. To make a more accurate identification, the rim and shoulder are necessary. The earliest securely identified dolia, on the other hand, usually come from contexts that are dated to the middle Republican period, cf. Nicoletta 2007, Bergamini 2008.

decorated, and were probably designed as a multipurpose vessel. The production of dolia too, at least in Latium, Tuscany, and Campania, is not well attested until the third century BCE or later, before which only a handful of dolium production sites were tenuously identified (**Fig. 3.7**).[145] This survey of the limited available evidence on the origins of the dolium also suggests that, over time, the scale of dolium production increased and became folded into brick and tile production (**Figs. 3.8-10**). According to both textual and archaeological evidence, then, I posit that dolia were a distinct kind of vessel with a specific design and purpose, and they were first designed and developed by specialized potters, perhaps known as *doliarii*, during the third century BCE, or slightly earlier, when the Roman wine industry became more lucrative and profit-driven, and exported products overseas.[146]

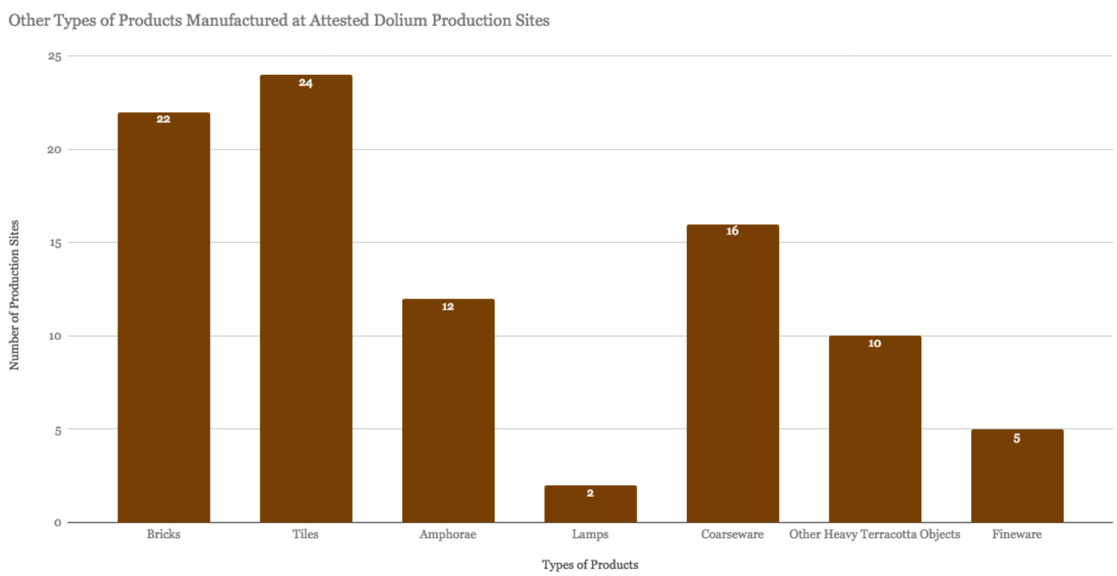


Fig. 3.8. Chart of products manufactured with dolia at attested production sites. Information from Olcese 2012, Bergamini 2008, and Tol and Borgers 2016. Dolia were never the sole product of a workshop (the only exception is a small 2nd c. BCE rural production site in the Pontine Plain). They were often produced with other *opus doliare* products (bricks, tiles, mortaria, architectural terracottas), but they were also produced alongside amphorae, coarseware, and, less often, fineware pottery.

145 The data are mostly from Olcese 2012; data from Scoppieto in Umbria (Bergamini 2007) and the Pontine Plain (Tol and Borgers 2016) have been included. The identification of dolium production sites depends on very fragmentary evidence, usually only discarded material or wasters. We lack sufficient archaeological remains that tell us about dolium production and its organization in these spaces.

146 A *doliarius* is attested on a second century CE funerary inscription (bilingual Greek and Latin). Cf. Zimmer 1982. According to the *TLL*, *doliarius* is associated with places where dolia are or originate. The use of *doliarius* to for an occupation was uncommon, but was acceptable enough to use on an epitaph.

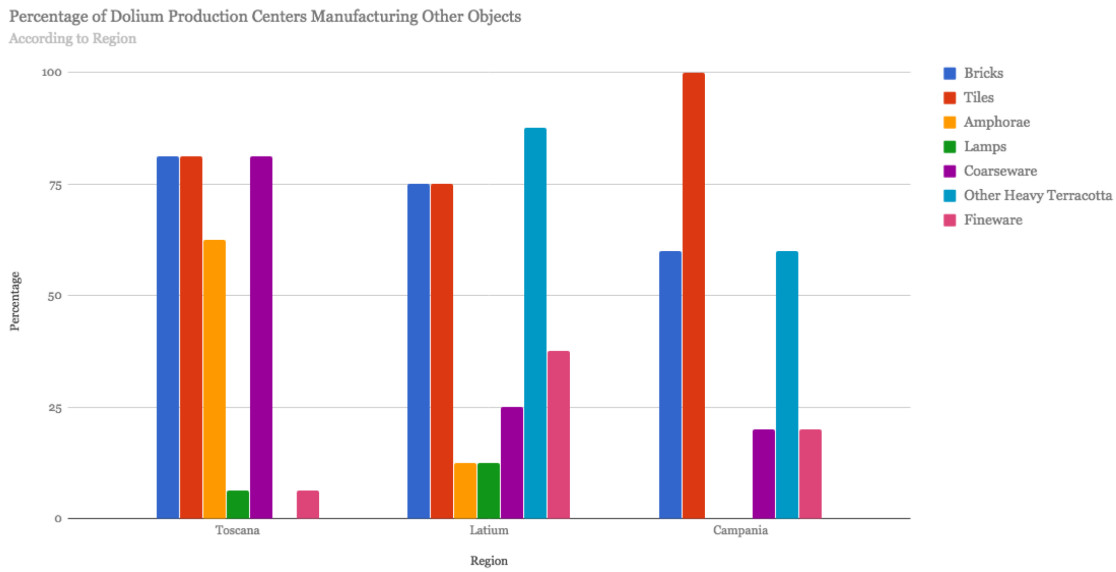
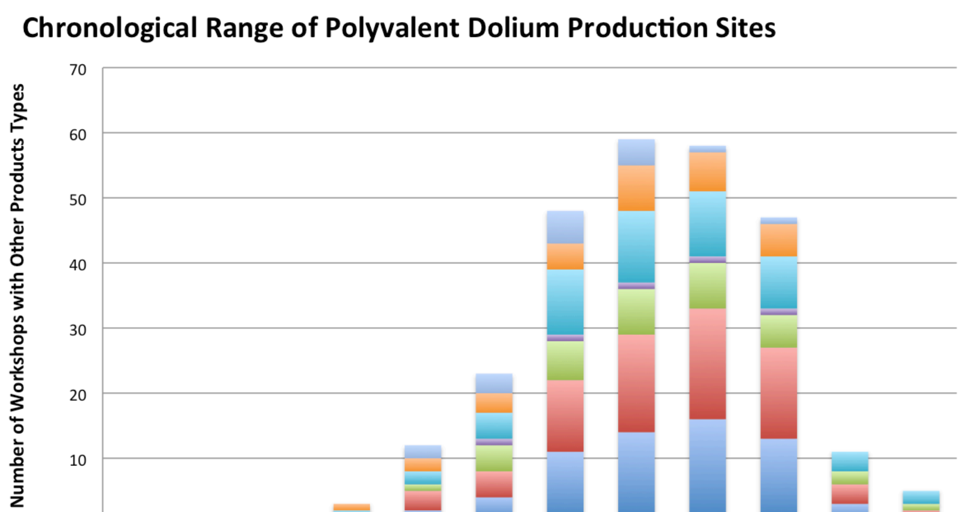


Fig. 3.9. Other Types of Objects Manufactured in Dolium Production Sites in Tuscany, Latium, and Campania, based on Olcese 2012 ('other heavy terracotta' includes mortaria, architectural terracottas, miscellaneous terracotta materials). There is a common overlap between production for dolia and brick and tiles in all three regions. There is more overlap with amphorae and coarseware pottery in Tuscany; in both Latium and Campania, dolia are commonly produced with heavy terracotta items.



	7th c. BCE	6th c. BCE	5th c. BCE	4th c. BCE	3rd c. BCE	2nd c. BCE	1st c. BCE	1st c. CE	2nd c. CE	3rd c. CE	4th c. CE	5th c. CE
Fineware	0	0	0	0	2	3	5	4	1	1	0	0
Other Heavy Terracotta Objects	0	0	0	1	2	3	4	7	6	5	0	0
Coarseware	1	1	1	1	2	4	10	11	10	8	3	2
Lamps	0	0	0	0	0	1	1	1	1	1	0	0
Amphorae	0	0	0	1	1	4	6	7	7	5	2	1
Tiles	0	0	0	0	3	4	11	15	17	14	3	1
Bricks	0	0	0	0	2	4	11	14	16	13	3	1

Fig. 3.10. Other product types made at dolium production sites over time, based on Olcese 2012. By the 1st c. BCE, dolia were commonly produced along bricks and tiles.

3.3 *Dolium Production.* Dolia were by far the most expensive pottery one could buy in antiquity. Although made of clay, these vessels were much more expensive than their smaller ceramic cousins, costing a thousand *denarii*, about 2,500 times more than a ceramic lamp.[147] Dolia fetched such high prices not only because of the great quantity of material needed to build these massive vessels (hundreds of kilograms of clay), but also because of the high levels of skill and amount of time required for this enterprise.[148] Unlike other types of ceramic containers, usually only specialists produced dolia.[149] Sometime during the first or second century CE, a certain L. Aurelius Sabinus called himself a *doliarius*, which we should understand to have been an expert dolium maker (**Fig. 3.11**).[150] Agricultural handbooks considered dolia to be expensive yet essential investments and equipment for producing wine and olive oil, even designating these vessels as architectural elements that belonged on the premises.[151]

Λ(ΟΥΚΙΩ) ΑΥΡΕΛΙΩ ΛΑ/
ΠΥΝΩ ΟΝΑΓΡΩ/
ΚΑΙ ΑΥΡΕΛΙΩ□

L(UCIUS) AVRELIVS SABI/
NVS DOLIARI/
VS FECIT SIBI/
ET SVIS

Fig. 3.11. Drawing of a funerary altar for a *doliarius*, from Zimmer 1982.

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147 *Diocletian's Price Edict* 15.97-101: a large dolium cost 1,000 *denarii*; a set of ten lamps cost four *denarii*. Unskilled laborers usually earned 25 *denarii*/day, though weavers earned 12-16 *denarii*/day.

148 Andrew Beckham, a modern-day wine producer who makes his own dolia in which he ferments his wines, uses 900 pounds of clay to build a dolium with a capacity of c. 750 liters, comparable to the largest dolia at Pompeii; the average volume for a dolium at Ostia is just over 1,000 liters. Adam Field, a potter, uses 350 pounds of clay to build a large Korean fermentation jar known as an *onggi*.

149 Plato *Gorgias* 514e; Curtis 2016, 589: "Socrates, in Plato's Gorgias (514e), for example, referring to a proverb cautioning against attempting a more complicated task before mastering a simpler one, describes someone who begins his training to become a potter by first attempting to make a *pithos*, or, as we might say, by putting the cart before the horse."

150 Zimmer 1982, 206; *CIL* X 403=483 presents a first to second century Greek and Latin bilingual funerary altar. The Latin text describes the L. Aurelius Sabinus as a *doliarius*.

151 *Digest* 33.6.3 and 33.6.15 discuss the status of dolia; they were not considered containers that were 'owed' with wine that was sold.

There is no detailed written material from the ancient world that can tell us exactly or specifically how difficult, risky, or demanding this process was. Ethnographic studies of the few places that still practice this scale of traditional pottery production shed light on how people in antiquity constructed these vessels, how much material and time was necessary, the firing conditions, along with other logistic elements of the production process.[152] The few large-scale pottery and terracotta workshops still in operation today often share the same practical concerns regarding production, such as having access to the right kind of high quality clay.[153] Dolium production required particular clay to achieve a large size and structural integrity, and to be fired properly to make the vessel a suitable wine container. This was such a serious concern that buyers were advised to visit the workshops and clay beds to evaluate the clay before purchasing a dolium, with the result that workshops in certain areas gained better reputations.[154] Getting and preparing the raw materials for dolium production was not a simple process, but required some practical knowledge and was probably a seasonal activity.[155]

Making dolia was also very complicated, time-consuming, and onerous. These vessels were generally too large to throw on a standard potter's wheel and were either coil- or slab-built over the course of at least several days.[156] For the coil-building process, the potter(s) would have thrown the dolium base on the wheel, before transferring it either to a flat surface or onto a turntable or a slow-turning wheel for the remainder of the process. The potter(s) then gradually added coils to build up the dolium; the vessel could only be built up a certain amount per day to allow the added clay to dry and strengthen before more coils were added (**Fig. 3.12**).[157] Contemporary potters making large dolium-like vessels coil-build their pots. Slab-building involved affixing sections of the vessel together (**Fig. 3.13**); but a dolium was

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152 Blitzer 1990 is the most useful source for understanding the production and distribution of pithoi. Based on ethnographic studies of the production of large storage vessels in Greece, each vessel would have taken several days to form. A large *pithos* required twenty days to form, ten days to dry indoors, and another ten days to dry outdoors before it could be fired in the kiln. With 19th c. kiln technology, a load of six pithoi could be fired, requiring c. 12-14 hours of firing and several days to cool.

153 Workshops in Grottaglie (in Puglia), parts of Tuscany, certain areas in China, etc. are found near well-known clay sources that have ideal properties for the type of pottery production the workshops specialize in. Yet with globalization and large-scale shipping and transportation, some of these workshops no longer depend on local clay sources, but instead purchase industrial clay, prepared by factories.

154 *Geoponika* 6.3. Cato *de Agri Cultura* 135 mentions Trebla Alba and Rome as major production centers.

155 Acquiring and preparing the clay for dolium production probably differed little from clay preparation for brick production; this was a seasonal task: digging clay generally took place between the late summer or early autumn and was left to weather until the spring, a process necessary for the clay to become more workable. DeLaine 1997 discusses the seasonality of these tasks. Furthermore, the clay had to break down to allow the material to be further tempered and processed, with both the removal of large impurities and addition of stable ballast. Although the groggy clay body used for the building of dolia was stable, an impurity could lead to cracks radiating from the impurity either during the drying process or, if it was small enough to make it through the air drying without affecting the pot, during the firing process.

156 Peña 2007a. Andrew Beckham has a custom-built, high-powered potter's wheel to throw dolia.

157 Blitzer 1990: only one coil was added per day.

probably too big to be made this way.[158] The size of the vessel, and the large amount of ceramic material used to construct it, also necessitated a large space for production and drying, long drying and firing times, and a large kiln. The amount of time employed for the production of vessels of similar size and shape by craft and traditional potters today suggests that the production of dolia likely required several days to even months for the forming process, a week to three months for drying, twelve to sixty hours for firing in the kiln, and several days to cool in the kiln.[159] During this process, plenty could go wrong: their shape could be distorted as they were formed; cracks could appear during forming or drying; they could break during drying or even firing.[160]

Fig. 12. (L) Contemporary Burmese potter coil-building a traditional storage jar.
Fig. 13 (R) Contemporary potter slab-building a vase.

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158 Several practicing potters have stated that slab building would not have been an ideal or feasible method for constructing vessels the size of large Roman dolia. The rates of shrinkage in slab-building may have presented problems for the manufacture of very large vessels. Furthermore, slab-building was probably much more time-consuming than coil-building a dolium. On the other hand, Rando 1996 notes that there was no evidence of coil-building for the dolia from the Diano Marina shipwreck he studied, so he deduced that they must have been constructed via slab-building; also cf. Peña 2007a, 35, 218.

159 These figures are mostly based on Andrew Beckham's dolium production and Blitzer 1990's ethnographic study of modern day storage vessel production in the Aegean; one contemporary *qvevri* maker says it takes three months to coil-build a large batch of *qvevri*. Due to the long period of time required for the building, drying, and firing of dolia, the actual production of these large vessels probably took place during the dry months of April to September, the same months during which took place brick and tile production, shipping in the Mediterranean, and many agricultural activities; cf. DeLaine 1997, Erdkamp 1999, Horden and Purcell 2001, Shaw 2014, Hawkins 2017.

160 The strawberry-shape of a dolium was difficult to make. Kang 2015 describes the trials and failures a contemporary *onggi* potter met when trying to change from a straight-sided style *onggi* to one with a belly; there were problems with finding and preparing the right clay and building and firing the vessels.

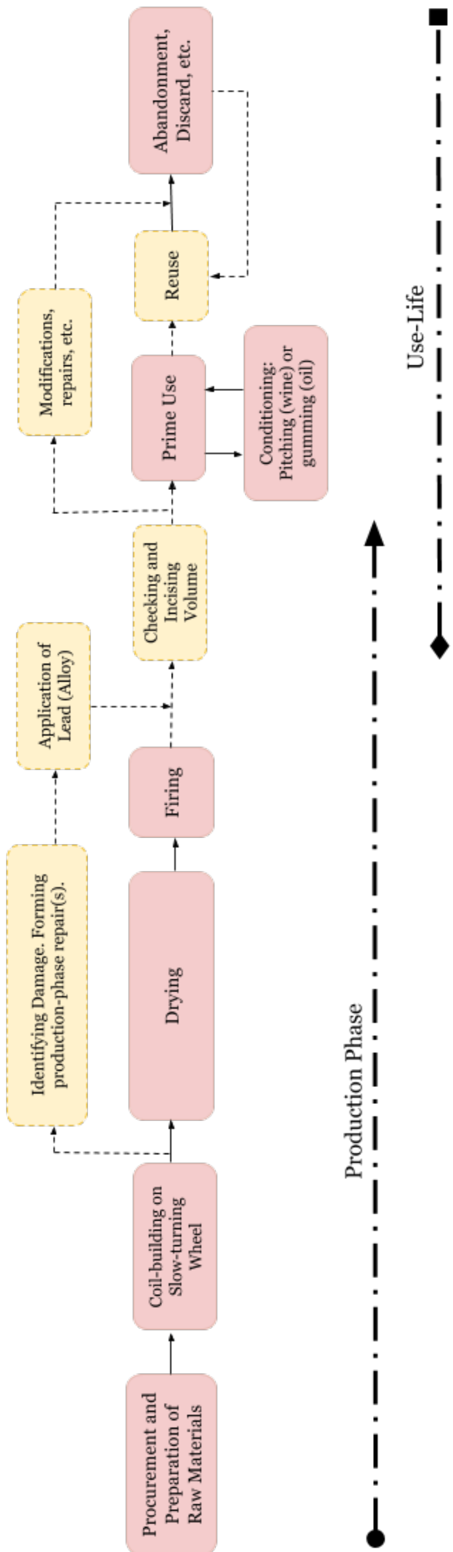

Fig. 3.14. Flow Diagram of the 'life cycle' of a dolium. Yellow boxes represent optional stages.

The production of dolia therefore consisted of a series of processes that, at times, required specialized knowledge and skills: the procurement of clay; the preparation and refinement of the clay; throwing the disc base on a wheel; preparing coils of clay (and scoring the surfaces of the edges); adding clay coils onto the vessel as it was being built up; forming the rim; regularizing any cracks in the first phase of mending the vessel; building a kiln around the vessel(s) or loading the vessel(s) into a permanent kiln structure; firing and cooling the vessel(s); unloading the vessel(s) from the kiln; applying lead or lead alloy to the production repairs; and possibly measuring and labeling the capacity of the vessel (**Fig. 3.14**); in this study, all stages involved in the production of a dolium, which typically took place in the workshop, are considered *production-phase*, whereas stages after production, including the dolium's acquisition, maintenance, and (re)use, are considered *use-life*.[161] Although the methods of producing dolia were limited (coil- or slab-building), the scale and organization of labor could differ greatly, with implications far beyond dolia that could inform us about craft production, landownership and management patterns, and agricultural economies.

Little is known about the production of large ceramic storage jars, especially for periods earlier than the first century CE.[162] Based on archaeological evidence for *pithos* and dolium production as well as ethnographic studies, potters of different workshop set-ups could have made the vessels, which also means different implications for the locus of manufacture. Itinerant potters specializing in dolium production could have visited towns to practice their craft, making vessels at the place of use. Alternatively, small, specialized dolium production centers could serve a minor area, manufacturing dolia for local destinations. On the other hand, larger dolium production centers could serve entire regions, and perhaps even export vessels to more far-flung destinations. These arrangements came with certain advantages and disadvantages, and the ways in which labor and production were organized may have varied depending on the period and the location of the places in question.

Dolia were large and heavy vessels that were cumbersome to transport. If an itinerant potter were commissioned to make a dolium or several dolia, the potter could build and fire the vessel at its destination, eliminating complicated transport. The disadvantage was that the potter only had the tools that he or she could carry, would be limited to the local clay, and would have to build a kiln around the pot. The quality of the local clay could have been insufficient for dolia and building a makeshift kiln for a large storage vessel could have been problematic. It was imperative to fire the vessel at a high enough temperature to render the vessel liquid-tight, and with the proper timing otherwise cracks would form and the vessel's quality would be compromised; these were all difficult conditions to control. Overall, a dolium with major production flaws or that had been improperly fired would have been a serious loss for the potter, since s/he invested a significant amount of time, energy, and materials in building a dolium.

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161 For discussion regarding the life-history of dolia, cf. Peña 2007a, 324-325; also 213-227, 35, 46-47, 194-196. Although Peña outlines eight behavioral practices, this project focuses on manufacture, distribution, prime use, and maintenance (the others being reuse, recycling, discard, and reclamation).

162 Pithoi production, especially from the Bronze Age, has received more attention; this is probably due to the strong interest among pre-historians to study (social) storage and its relationship with political authority. Cf. Christakis 2008, 2005, 1999; Giannopoulou 2010.

With the workshop set-up, many of these issues were alleviated, and there were better controls over the conditions of the production; the risk was not as great for the potter, but the workshops required access to a stable market and reliable transportation. Workshops were often in less densely populated areas where there was ample space and access to materials such as high-quality clay, water, and wood.[163] Having a permanent space and facility also meant that artisans had access to permanent equipment, such as vats and kilns. Permanent structures and equipment provided consistency in the production process. By the time Cato was writing *de Agri Cultura*, not only were dolia made in specific workshops, which specialized in *opus doliare* products (bricks, tiles, mortaria, dolia), there were also specific places with reputable workshops.[164] There were 'urban' *opus doliare* workshops, situated along the Tiber River within 50 km of Rome, that supplied the city of Rome and its markets, and 'extra-urban' or 'municipal' *opus doliare* workshops in other parts of Italy.[165] Furthermore, stamps found on dolia indicate that there was also a range in the scale and organization of workshops.

Many workshops stamped their ceramic and terracotta products, including fineware pottery, amphorae, bricks, tiles, mortaria, and even dolia.[166] The few stamps found on dolia differed from other types of stamps, however, and how to interpret them is still uncertain. But understanding how other *opus doliare* products are stamped could provide important insights and guidelines. Among the various *opus doliare* products, Roman brick stamps of the second century CE contained the most detailed information.[167] They were standardized and formulaic, and featured information regarding the *figlinae, dominus*, and *officinator*. The relationship between these figures has been widely debated, but the prevailing view is that the *figlinae* should be interpreted as "clay lands" and referred to territorial districts, which were owned/managed by the *domini,* "landlords." *Officinatores* were entrepreneurs who could move from brickyard to brickyard and rent from different *domini*, but their status, role, and relationship to the *dominus* have not been fully fleshed out; "the term *officinator* still may describe anything from a slave foreman in his master's service to a powerful industrialist of equestrian rank."[168] Stamps were most likely used for internal purposes, that is, for the organization of production within large production sites with several *officinatores* (entrepreneurs) responsible for different batches of

163 Tol and Borgers 2016: there was a dolium production site (no other products found) in the Pontine Valley, dated to the second c. BCE.

164 Taglietti and Zaccaria 1994; Uboldi 2005; Lazzeretti and Pallecchi 2005. Cato *de Agri Cultura* 135 advises purchasing dolia from workshops in Trebla Alba and Rome. On the other hand, Cato's readers were probably mostly elite landowners; small, rural sites removed from these commercial networks were probably served by small, local workshops or itinerant potters.

165 Steinby 1981.

166 Manacorda 1993: Although ceramic and terracotta objects were generally stamped, there was no single reason why. They were often stamped as part of the production phase, as a form of internal control over a workshop's production, which was especially important for large-scale *opus doliare* workshops that had employees responsible for various tasks and operating on different hierarchies. Stamps were often also used to testify to and guarantee the quality of a product, include information for the customer (sometimes this also indicated the place of production), or as a way to control and limit the export of products.

167 The literature on this subject is vast. For a succinct overview, cf. the introduction in Bodel 1983.

168 Bodel 1983, 4.

goods, where the stamps were crucial in distinguishing one *officinator*'s products from another's.

Mortaria, a type of open bowl with thick, heavy flanges and a gritty surface used for pounding or grinding food, also formed a class of *opus doliare* products.[169] They often featured stamps on the rim that are small and more cursory, usually consisting of two registers. The first register typically referred to the *dominus* of the clay beds, who was most often a senatorial figure or member of the imperial family. The second register could refer to the *officinator* (the entrepreneurial figure), the actual producer of the vessel, or a *vilicus* (slave manager) if slaves made the products. Stamps on mortaria probably referred to the internal organization of production in the *figlinae* or *praedia*, and also could have attested to the quality of the product.[170]

Dolium stamps, found on the rim, were generally short with the name of one person, usually in the genitive, who was most likely the owner of the workshop. Unlike bricks, dolium stamps were not formulaic and their scarcity and brevity have precluded systematic studies.[171] Although most dolium stamps seem to indicate the owner of the workshop, some of the dolia featured a second stamp with another name and/or pictorial symbols. These additional stamps could be a reference to the *officinator*, the *doliarius*, or to the consumer.[172] The following sections will discuss the evidence at Cosa, Pompeii, and Ostia more in depth.

Overall, studying the dolium industries brings to light the technology and organization of labor for a particular type of craft production that enabled the large-scale, long-distance movement of goods in the ancient world. Studying dolium production, in particular, reveals not only how craftsmen developed skills and techniques for building big vessels, but also how the industry shaped and was shaped by patterns of land and workshop ownership and management. Thanks to the socio-economic conditions of central Italy, namely the growing concentration of wealth among elites practicing viticulture and operating *opus doliare* workshops, dolium craft industries emerged and grew, becoming an increasingly attractive economic activity for landowners, especially members of the senatorial and imperial families.

3.4 *Methodology.* For a detailed view of dolium production in west-central Italy, I examined and documented over four hundred extant archaeological remains of vessels and their fragments from the 'production' sites of Cosa and Pompeii, and the

169 For succinct overview, cf. Frazzoni 2016. For comprehensive work on mortaria, cf. Pallecchi 2005. A substantial number of mortaria have been found in the provinces such as Britain (cf. Cool 2006 for interesting discussion of mortaria in Britain), Gaul, Egypt, Asia Minor, and Greece. Stamped mortaria originating from Rome have been found as far afield as Antinoupolis, cf. Spanu 2015 for an example.
170 Frazzoni 2016.
171 Bloch 1948 and the *CIL* are the most comprehensive publications for dolium stamps. Although new dolium stamps have been published, they usually appear in a variety of journals (sometimes obscure), excavation reports, etc. making it difficult to study the dolium stamps collectively. Dolium stamps usually provide names of individuals unattested elsewhere.
172 Cf. Manacorda 1993 for discussion of passages from the *Digest* (18.6.1.1-2, 19.1.6.4, 21.1.33).

'consumer' site Ostia.[173] This involved observation of cracks, seams, and parts of vessels that could reveal how they were produced and how they were damaged, including production-based flaws. The documentation of these containers included recording any stamps or incisions on the vessels and measuring various dimensions, such as the inner and outer rim diameters, the height of the vessel, the maximum diameter of the vessel, its wall thickness, and the diameter of its base, in order to understand the vessels' morphologies and their capacities (**Fig. 3.15**).[174] I assessed the quality of the vessels by noting how compact and stable their materials and surfaces were, i.e. whether they flaked or crumbled easily.[175] When possible, the documentation generated three-dimensional scans of the dolia, which helped calculate the volume and capture the complete morphology of the vessel;[176] this was especially valuable for vessels embedded in architectural units or in the ground.[177] Overall, the majority of the work consisted of careful visual inspection with the naked eye, photography, a digital microscope (DinoLite), and a 3D scanner for evidence related to production, use, maintenance, and repair.[178]

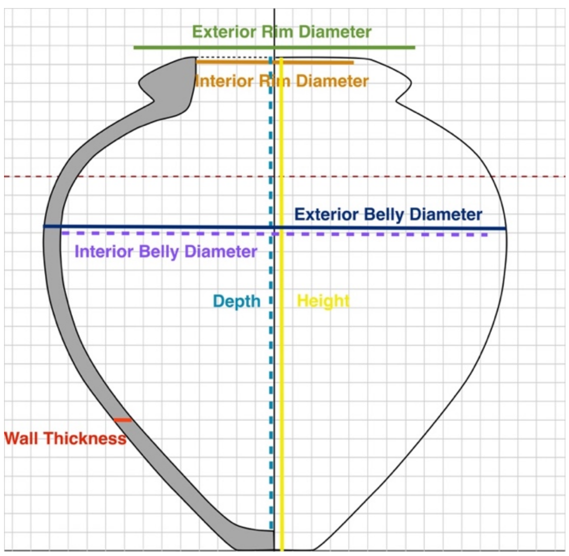

Fig. 3.15. Terms for dolium dimensions, adapted from profile drawing by Gina Tibbott.

While the bulk of the evidence for this study comes from direct examination of dolia and dolium fragments from the three case study sites, other forms of evidence are also

173 I studied c. 50 dolium fragments and storage jars, in addition to dolium lids, at Cosa; c. 100 dolia, c. 30 dolium lids, and c. 100 of a different type of storage jar at Pompeii, and c. 125 dolia at Ostia.
174 For more information on the object life-history approach employed, cf. Peña and Cheung 2015, Peña 2014. For detailed study of production, use, and repair of select group of dolia using this object life-history approach, cf. Cheung and Tibbott forthcoming.
175 *Geoponika* 6.3: a well-made dolium would produce a sharp, penetrating sound when struck.
176 Dolium capacities will be further discussed in **Chapter 5**.
177 Three-dimensional scanning was done with a small portable Occipital Sensor Structure 3D scanner fitted to an iPad, and volumes were generated by different software: MeshLab and Rhinoceros.
178 Because this project does not aim to generate a typology of dolia, producing profile drawings was not a priority in the documentation of dolia at this stage of the project.

informative. These include textual sources, iconographic representations, and comparative evidence. Among the textual sources, legal codes and treatises on farming, such as Cato's *de Agri Cultura*, Varro's *de Re Rustica*, Columella's *de Re Rustica*, and the tenth century compilation *Geoponika*, as well as Pliny's *Naturae Historia* are particularly useful. A small number of iconographic representations, including reliefs, mosaics, and fresco paintings, portrays how dolia were used. Comparative evidence, primarily from ethnographic studies contemporary pottery making, can be helpful for illuminating some of the logistical aspects of manufacture, maintenance, and use of dolia. These sources are not unproblematic or without biases of their own, but they can provide unique insights and details to enhance or clarify what can be gleaned from the material evidence.

Fig. 3.16. View of horizontal cracks forming between coils on a dolium (Pompeii I.22 no. 5).

Fig. 3.17. View from below of crack between dolium base and first body coil (Pompeii I.22 no. 7).

Fig. 3.18. Detailed view of unsmoothed seam between coil on dolium interior wall (Pompeii I.22 no. 5).

Since dolia were important storage vessels for liquid products, they have been found in abundant numbers, especially in Pompeii and Ostia. Some dolia at Pompeii were not buried at the time of the eruption of Vesuvius and offer the most and best evidence for dolia production in west-central Italy:[179] the Pompeian dolia were coil-built on a slow-turning wheel or turntable (**Fig. 3.16**). The potter started with a disc of clay to form a small base, usually between 6 and 10 cm thick, and gradually added hand-squeezed or rolled coils, likely just a single coil per day to allow the coil to dry sufficiently in order to support the weight of the next coil (**Fig. 3.17**). The potter generally smoothed the seams between the coils as the vessel was built up (**Fig. 3.18**). Since it was critical for the previous coil to bond properly with the next, otherwise cracks would form, the potter sometimes scored surfaces of the coils that would come in contact with one another other to facilitate the joining (**Fig. 3.19**).[180] For the rim, the potter formed a smaller coil, onto which s/he molded the lip and upper surface of the rim, sometimes after scoring the surface of the rim coil (**Figs. 3.20-21**). Although potters strove to minimize the chances of production flaws and defects, we will see in the next chapter that they eventually operated at a new level by preemptively identifying and treating potential damage.

Fig. 3.19. (L) Detailed view of dolium scored coil edge, at Pompeii I.22.
Fig. 3.20. (R) Pompeii I.22 no. 9, view of seam between rim coil and lip.

179 Dolia and dolium fragments from Cosa and Ostia are not necessarily well preserved, offering limited views for understanding their production; the best, most illuminating evidence comes from Pompeii, which will be discussed in detail. Dolia from the House of Stabianus (I.22) offer the most complete views of the vessels; cf. Cheung and Tibbott forthcoming.

180 Carrato 2017, 135ff also noted scoring marks on dolia in Gaul. Based on techniques of traditional potters, the potter probably added a wet cloth over the last coil to prevent the coil from drying too quickly from the upper surface. Rando 1996 describes the ; Peña 2007a, 218 brings up the possibility that one dolium with distinctive cracks at Ostia was slab-built; it may have been, but the cracks could also be a combination of dunting cracks and coil fractures.


Fig. 3.21. Scoring on rim coil (at break) for addition of rim lip (Pompeii VII.6.15 no. 1).

Cracks and seams on dolia at the sites of Cosa, Pompeii, and Ostia suggest that the dolia were all coil-built, but their quality varied. Moreover, based on the dolium stamp evidence, there were major differences in the organization of labor and scale of production among the different sites. To have a better grasp of these differences and what they might mean, this chapter also discusses the preliminary results of an ongoing collaborative study generating mathematical computations and models to estimate material use, fuel consumption, and firing conditions in dolium production.[181] The following sections will survey the evidence for dolium production at the three case study sites to track developments in the craft, namely by observing whether there were attempts to produce larger, standardized, and higher quality products.[182]

181 An ongoing collaboration with mathematician Stanley Chang (Professor of Mathematics, Wellesley College) and archaeologist and contemporary potter Gina Tibbott (PhD candidate in Anthropology, Temple University) is producing computations and models using linear regression, 3D modeling, and the quintic polynomial to estimate vessel capacities, material use, and fuel consumption. The next stages will include work with contemporary potters to test firing conditions in order to model fuel use and kiln conditions.

182 Osborne 2017: although standardization is so obviously advantageous to us today, "standardisation enables people to have some confidence that the (class of) action or object in question reproduces in all essentials some other action of object" (123); in antiquity, standardization guaranteed the quality and functionality of an object, helping lower transaction costs.

3.5 ***Cosa.*** Evidence from Cosa overall is sparse, limited, and fragmentary, especially compared to the dolia and dolium-related materials at Ostia and Pompeii, but it provides some of the earliest evidence of dolium use in urban settlements and helps visualize how the craft developed.[183] Most of the diagnostic dolium fragments date to the early second to late first century BCE, and some fragments, primarily body sherds, were reused in second century CE contexts. These dolia were principally found in fills for raising the level of floors, but occasionally in houses too, so they are extremely fragmentary and lack context. Dolium fragments from previous excavations were diagnostic fragments, primarily rim fragments, and one wonders whether non-diagnostic fragments such as body sherds were simply discarded or were not even identified.[184]


Fig. 3.22. (L) A small dolium lid from Cosa (CE1633/23).
Fig. 3.23. (R) A large dolium lid from Cosa (C70.485).

Some rim fragments were from large dolia that are typically found in wine production or storage facilities (**Table 3.1**).[185] Several diagnostic dolium fragments are relatively similar in size, suggesting that dolia of such a scale were generally made with a certain rim size in mind. Although it is impossible to standardize the production and dimensions of such massive vessels, parts of the vessel, such as the base and rim, were easier to control. Most of the large dolia had rims with an inner rim diameter of less than 60 cm, which would have fit well with

183 The majority of dolia and dolium-related objects were discovered in the early, American Academy in Rome sponsored excavations and formed part of a cursory publication on the utilitarian pottery finds (Dyson 1976). Current excavations of the bath complex at Cosa have yielded some dolium fragments, which were reused as fill; both diagnostic and non-diagnostic fragments from the current Cosa Excavations project were collected and studied. The materials are currently housed in the storerooms of the Cosa Museum under the auspices of the Polo Museale di Toscana.

184 The 2013-present Cosa excavations have recovered a few dolium body sherds in fills from the bath complex; during these excavations, it became apparent how easy it was to mistaken dolium body sherds for bricks or tiles. Storage space has always been an issue at the Cosa museum, resulting in the discard of select finds over the years.

185 There were also a few other types of storage containers that are smaller. It is unclear what these containers stored, but they could have held a variety of foods.

the large dolium lids that were found on site (**Figs. 3.22-23**).[186] These large dolia were mostly similar in morphology and scale, but there was a wide range in the types of ceramic fabric as well as the form of the rims, suggesting that different workshops provided dolia to Cosa (**Fig. 3.24**).[187] Moreover, most of the dolia were not fired well, resulting in either friable material or unstable surfaces that flaked or rubbed off easily.

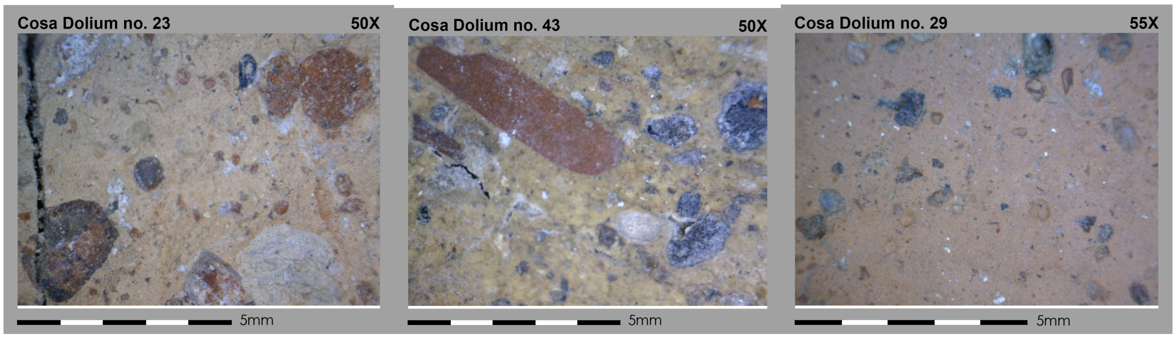

Fig. 3.24. Microphotographs of several different dolium ceramic fabrics at Cosa.

Fig. 3.25. Dolium rim with stamped surface showing 'H' in triangular border, Cosa.

Of the approximately fifty dolium fragments examined, only three preserve a stamp (**Table 3.2**). Unfortunately, it is impossible to say anything definitive about these stamps. The most brief and stylized stamp is from a rim fragment, which features a small letter 'H' in a triangular border (**Fig. 3.25**); there are at least three possible interpretations. The fragment was found in the 1972 sounding excavations of the settlement's horreum, so the vessel might

186 The only two base fragments are larger than those found at Pompeii.

187 If dolium production of the region was part of brick and tile production, Gliozzo 2014 found that bricks and tiles of Cosa were made with clay from three clay sources.

have been stamped with an H as an abbreviation for its destination in the horreum;[188] if that was the case, then, this would mean the stamp was utilized on the vessel during its production phase to mark a vessel that was made for a customer who purchased the dolium in advance. The stamp could have also been used for bookkeeping during the production process as a means to keep track of how many dolia were produced and by whom. Most of the stamps used for recording internal production during the first and second centuries CE were, however, more formulaic and detailed; yet it is possible that the early date of this dolium and its stamp, second century BCE, was a time when internal record-keeping in workshops was more abbreviated and informal. Another possibility, though unlikely, is that the H as part of a system of labeling the dolia in the structure (possibly as the eighth dolium), but no other dolium fragments have been recovered from these soundings and it seems gratuitous to have numbered the dolia in a room.[189]

Fig. 3.26. Dolium rim with stamped surface: 'L REMIO C F,' Cosa.

Two other, longer dolium stamps, both featuring names, are preserved. One dolium rim fragment of the late second or early first century BCE, found at the Temple of Jupiter, features a stamp bearing the text L· REMIO· C· F (**Fig. 3.26**).[190] The name is also otherwise

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188 Brown 1984.

189 The only type of identifying marker on dolia are incisions that mark capacities, which will be discussed to some extent in this chapter and in chapter five.

190 Bace 1984, 172 D1 is the only publication for this stamp; the other dolium stamps have not been published.

unattested, but could be related to the more common name Remmius; a Remmius of the Republican period has been attested in Etruria.[191] The name of this stamp is in the dative or ablative, whereas most other dolium stamps feature a name in the genitive or nominative; if this is the use of the dative case, the stamp could have been used to indicate ownership of the vessel, that this dolium was "for Lucius Remius, son of Gaius." Presumably the customer ordered the vessel in advance and would have provided his own stamp for this purpose. The other possibility is that the name was in either the dative case to indicate possession or in the ablative case to designate the origin of the vessel; this is probably the more likely explanation, though the use of either the dative or ablative case is unusual and differs from later stamps.

Fig. 3.27. Dolium stamp on rim: 'C TVRI,' Cosa. Photo courtesy of Christina Cha.

On the rim of the largest dolium fragment preserved, dated to the first century CE, was a small rectangular stamp with the name C· TVRI, which was most likely to indicate the estate or workshop owner (**Fig. 3.27**). The name is otherwise unattested, but was perhaps the name of an individual who owned a local dolium production center in the area. This might have been a means to attest to the quality of the vessel by identifying its workshop, and this dolium is the most capacious and well-made (and well-preserved) dolium found at Cosa. Also on this dolium was an incision of a pictorial symbol, likely depicting an anchor (**Fig. 3.28**). It was incised post-cocturum, suggesting that the symbol was added later, perhaps for and/or by the customer.

191 *CIL* I[2] 2063; Bace 1984, 172 suggests that this Remmius could be the origin of the Remius of L· REMIO· C· F.

Fig. 3.28. Post-cocturum incision, possibly of an anchor, on dolium shoulder, Cosa.

Although there are only three examples of stamped dolia at Cosa, they could show different reasons dolium products were stamped: the stamp for C· TVRI, a name in the genitive, was likely used for internal production bookkeeping purposes within the workshop (if there were different *officinator* figures and/or workshops shared kilns) and/or as a way to guarantee the quality of the product. Within the corpus of dolium stamps, this was the most common purpose and form. The purpose of the other two stamps, however, is less clear and deviated from this pattern. The stamps L· REMIO· C· F and H may have been applied to identify the customer and owner of the vessel. With this use, this suggests that either the workshop had to reserve the vessels for their customers (and that possibly the customers specifically chose those dolia) and/or that dolium production in these workshops were made to order, rather than a workshop producing dolia to be sold later, brought to the market, or distributed by merchants. Another interpretation of the 'H' letter, although less likely, is that it was a method to number the vessels in their place of use; this would have meant, then, that there was a close relationship between the pottery features and architectural planning for the structure. Although there is no definitive way to interpret these stamps at the moment, the Cosan dolium stamps differed from dolium stamps from the Vesuvian region and the urban area of Rome and Ostia, suggesting chronological and/or regional differences in the scale and organization of workshop operations.

With the overall paucity of dolium fragments, the urban settlement of Cosa was probably far from or was only a minor destination and market for the dolium industries, receiving only leftover, second-rate products.[192] Since Cosa itself did not practice agriculture within the town walls, but was an urban nexus for its productive hinterland, the inhabitants did not invest significant resources in dolia.[193] Instead, agricultural activities, especially wine production, occurred in Cosa's hinterland as part of the local villa economy.[194] The dolia and other various storage vessels of Cosa were not robust or particularly well made, especially compared to dolia found in Pompeii and Ostia; workshops supplying Cosa shared some common product designs, but the craft had not developed highly enough to guarantee a standard product quality that would ensure long-term use.

3.6 ***Pompeii.*** Many storage containers are found throughout Pompeii, most of which are well preserved and have been left in-situ since the time of the eruption in 79 CE.[195] Pompeian dolia were typically found in shops and in planted areas, such as gardens, vineyards, and groves for the storage, fermentation, and/or processing of agricultural products. Although there were dolia of different sizes throughout the site, the dolia used for the fermentation of wine on production sites, such as the Villa Regina at Boscoreale, the Villa of the Mysteries, the Garden of the Fugitives (I.21.2), and the vineyard (II.5.5) across from the amphitheater, were the largest of the settlement (**Figs. 3.29-31**); smaller dolia were typically found in shops and bars. The numerous dolia as well as their excellent preservation and archaeological context offer a uniquely detailed view of storage and packaging practices of an agricultural town in the first century CE.

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192 The countryside probably had more dolia since numerous villa estates engaged in wine production and export, especially during the Republican period. Tol and Borgers 2016 found that, during the late Republican period, there was a local pottery production region in the Pontine plain with several workshops with a range of products (one specializing in dolium production, one producing dolia with building materials, another in building material and pottery, et al.). It seems as though some of those rural workshops marketed second-rate products.

193 With the fragmentary evidence, it is not possible to calculate production requirements, but it was probably only a small fraction compared to dolium production for Pompeii and Ostia.

194 Scholarship on this topic is abundant since there have been numerous projects on the economy of the *Ager Cosanus*. Some of the most notable projects include Settefinestre, survey projects, etc.; cf. Carandini et al. 1985; Rathbone 1981; Manacorda 1981.

195 Because dolia are heavy and unwieldy objects, most of them have been left in-situ after excavations, although some, such as the vessels from the Sarno, are placed in storage or mounted as decorative features for gates, gardens, etc. around the site of Pompeii. I was able to study c. 100 dolia and dolium fragments, as well as c. 25 dolium lids. There is also another type of storage container with a cylindrical shape that is commonly found embedded in counters and other architectural masonry in shops and bars in Pompeii. Although it has been frequently called a dolium, these jars were not proper dolia; they were also important storage containers, probably known as an *orca* or *seria* (see definitions in White 1975), and their production may have been related to dolia. Since these vessels are not dolia, they will not be discussed here, but will instead form part of a separate project on food storage containers in Pompeii.

Fig. 3.29. *Dolium defossum* next to press in pressing room of Villa of the Mysteries in Pompeii. Three other dolia are just outside this room.

Fig. 3.30. Three *dolia defossa* next to treading vat of Garden of the Fugitives (I.21), Pompeii.

Fig. 3.31. Ten *dolia defossa* in room adjacent to wine press of the vineyard formerly known as the *Foro Boario* (II.5.5), Pompeii.

Most of the dolia in Pompeii were left in-situ, but some offer rare views of the vessels that shed light on their morphology, dimensions, and how they were made (**Table 3.3**). Although it was impossible to build dolia with identical dimensions, dolium makers were at least able to standardize some aspects of the vessels. Dolium bases were always small (diameter c. 20 cm), smaller than those found at Cosa, while the thickness of the dolium's walls (c. 3-5 cm) allowed the vessel to reach a certain size.[196] Dolium makers formed rims of in set sizes, probably to fit with standardized lids that could be easily replaced (**Figs. 3.32-33**): (i) small dolia that could be covered with smaller lids (diameter c. 30 cm), (ii) dolia, usually used for fermentation, that could be covered with larger lids (diameter c. 50-52 cm), and (iii) very large, and uncommon, dolia that were closed with very large lids (diameter c. 85 cm).[197]

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[196] I thank John Ochsendorf for this suggestion. Based on several dolia, the widest part of the vessel was usually 25-30 times the vessel's wall thickness (I.8.15 n. 1; I.20.5 n. 1; I.21.2 n. 1; I.22 n. 8; IX.9.10 n. 1; Villa of the Mysteries n. 2).

[197] Varro *de re rustica* 1.13.6 warned that gases from fermentation could lead to dolia (and their lids) to burst and break. Taglietti 2015: dolium lid production was an industry often separate from dolium

Pompeian dolia probably never exceeded a certain capacity (c. 700 liters was the upper limit, the average was c. 500 liters for fermentation dolia), suggesting that the technology and perhaps also the resources for the manufacture of these vessels reached a certain limit, which potters were not able to, or at least decided not to, exceed without great risk.[198]

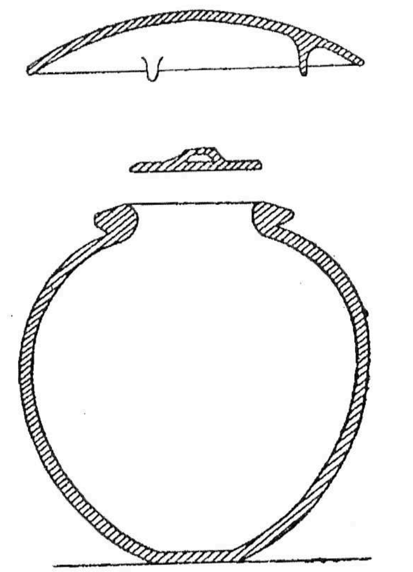

Fig. 3.32. (L) Dolium lid, diameter c. 50 cm, from Pompeii.
Fig. 3.33. (R) System of closing dolia with two types of lids, from Pasqui 1897.

Though the Pompeian dolia came from different workshops, there was a general design for the vessel.[199] The regularity and common features of the Pompeian dolia suggests that local workshops specializing in the manufacture of large ceramic and terracotta objects supplied dolia to Pompeii. The large dolia were occasionally well-fired with a red or light-red ceramic fabric. On the other hand, the small- and medium-size spherical dolia were all well-fired and had a light red ceramic fabric or a red or yellowish-red ceramic fabric, suggesting that dolium makers were able to exercise better control and expertise when manufacturing smaller dolia (**Fig. 3.34**).[200] The vessels generally had black sand, indicating that most of the dolia of Pompeii were produced locally, though a few stamped dolia were probably procured from workshops further afield.

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production; lids were made and sold separately because of how often and easily they broke and needed to be replaced.

198 The very large dolium rim for a lid of c. 85 cm is just a fragment, but the original vessel could have been much larger than other dolia on site. Another possibility is that the dolia reached a certain capacity in relation to their function. This will be discussed further in **Chapter 5**.

199 It is difficult to know exactly how many local workshops supplied dolia to Pompeii, but based on form and fabric, there were at least three.

200 There were a few vessels with different fabrics, but they were uncommon.

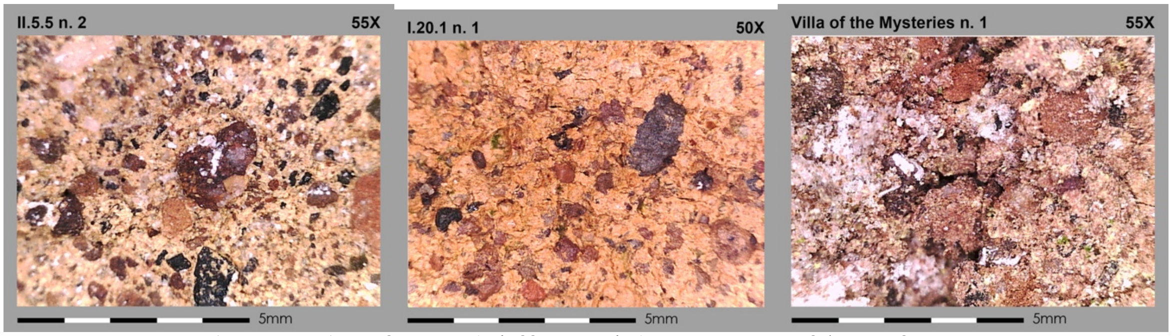

Fig. 3.34. Microphotographs of several different dolium ceramic fabrics from Pompeii.

Of the dolia examined in Pompeii, less than 10% of the vessels were stamped, all of which were large fermentation dolia and/or particularly well-fired and robust vessels (**Table 3.4**);[201] this is surprising especially given that bricks and tiles, by contrast, were so frequently stamped. Most of the dolium stamps featured one name, which probably referred to the estate owner; these were usually in the genitive case, such as a C. Naevi Vitalis, whose workshop also produced tiles (**Fig. 3.35**); the only attested slave, Phileros, found on a dolium has also been attested on a dolium found in Rome. The paucity of dolium stamps suggests that the local dolium production did not require stamps. Instead, the dolia that were stamped were likely done in order to attest to a particular level of quality of the vessel; certain workshops were probably reputable for producing high quality vessels and labeled their products to inform and attract potential customers. This practice would have been especially important for buyers purchasing dolia through merchants or from a market, and might explain why dolium stamps in Pompeii only appear on dolia from further afield.[202] Dolia could have also been stamped as part of internal bookkeeping for the workshop, especially if different workshops shared kilns and other spaces, but this was less likely given the paucity of stamps.[203] A few dolia bore stamp impressions that traced them to workshops that produced brick and tile products, some of which were found as far afield as Neapolis, and even Rome.[204] These stamped dolia were likely acquired from large-scale, specialized workshops in northern Campania and southern Latium.[205]

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201 The table includes stamps found on cylindrical jars as well since *CIL* and Bloch 1948 do not distinguish between the two different vessels and their production was probably related. The figure given above (10%) for stamped dolia is based on the dolia I examined in person, so it might have been higher.

202 Pompeians might have visited their local dolium workshops to buy dolia, and even transport them themselves, while dolia destined for the market were stamped.

203 Manacorda 1993; Lazzerretti and Pallecchi 2004.

204 According to *CIL* X 8047 17 and 8042 93, L SAGINI appears on both dolia found in Pompeii and on tiles in Naples.

205 Cf. Steinby 1993 on discussion of stamped *opus doliare* materials in Pompeii and their origins. Many dolia recovered from shipwrecks are thought to have been made in Minturnae, or at least these unique bulk wine transport ships were assembled in Minturnae; cf. Heslin 2011.

Fig. 3.35. Dolium rim with dolium stamp: C NAEVI/VITALIS (Pompeii VI 14 36).

Overall, the numerous dolia throughout Pompeii shed light on the dolium industries of the area. The standardized design, robustness, and set sizes of the vessels reveal an overall development of the craft in this area; potters were able to replicate the strawberry shape of the vessel, while minimizing the base and expanding the shoulder. Pompeians mostly acquired their dolia from local workshops, though some procured larger and higher-quality vessels from more distant workshops that had advanced the craft even more. Workshops made significant investment in dolium production; to support wine production and storage in the town of Pompeii, thousands of kilograms of clay were used to form just the dolia (much more was used for the other containers including amphorae and jars), and many more resources were expended to fire and then transport and install the vessels.[206] This serious investment was crucial since there was high demand for these vessels in Pompeii to supply the numerous vineyards and shops throughout the town.

3.7 *Ostia.* By the first quarter of the second century CE, Ostia underwent major renovations, with nearly two hundred dolia installed in just four storehouses: over one hundred dolia in the Magazzino Annonario (V.11.5); thirty-five dolia in the Caseggiato dei Doli (I.4.5); twenty dolia in the Magazzino dei Doli (III.14.3); and twenty-two in the Caseggiato dei Doli (I.19), a property that has been reburied (**Figs. 3.36-38**). The dolia were found in-situ, but since Ostia, unlike Pompeii, was occupied for centuries after the storehouses and vessels were installed, the dolia are not well preserved.[207] Inhabitants and visitors alike in the later periods altered these storerooms, sometimes changing their functions

206 According to different calculations based on linear regression and quintic polynomial models, dolia from Pompeii weighed between 120-660 kg and must have required substantial amounts of fuel to fire.
207 Although none of the vessels at Ostia present entire views, each property offers a piece to help construct the overall picture: the Magazzino Annonario gives us the interior and exterior middle walls; the Caseggiato dei Doli provides rims, upper walls, and incisions marking the vessels' volumes; and the Magazzino dei Doli preserves stamped rim surfaces. The Caseggiatio dei Doli (I.19) has been reburied. Although the vessels were left in-situ, they were out of use or reused after the second century CE.

or putting them out of use completely to claim the space as something entirely different.[208] As a result, the Ostian dolia are much more fragmentary and only parts of the vessels can be seen due to both their position and find spots.[209] Approximately one hundred dolia found in the three storehouses are still visible today, providing a view of food storage Rome's major port city during the second century CE.[210]

Fig. 3.36. View of Magazzino Annonario (V.11.5) from northwest corner.

[208] The floor of the Magazzino dei Doli was substantially raised; the dolia of the Caseggiato dei Doli were filled with molded terracotta objects and then covered over.

[209] There are a few free-standing dolia near the museum, but these were recovered from shipwrecks. The most visible, and studiable, 'terrestrial' dolium is in the Magazzino Annonario, but it is in an overgrown area and the base and lower wall are embedded in the ground.

[210] Grain and other goods were stored in numerous *horrea* found throughout the city, cf. Rickman 1971.

Fig. 3.37. View of Caseggiato dei Doli (I.4.5) from southeast corner.

Fig. 3.38. View of Magazzino dei Doli (III.14.3), linked to House of Annius, from south.

Although the dolia's capacities varied to some degree, their overall morphology, scale, rim sizes, wall thickness, ceramic fabric, and even their installations were standardized (**Table 3.5**). The storehouses were installed around the first quarter of the second century CE, and the dolia were arranged close together in mostly regular rows, leaving space for walkways. The dolia found in the various storerooms of Ostia are massive, with thick walls (c. 5 cm) and wide rims (c. 60+ cm), and among the largest in the Mediterranean (**Fig. 3.39**).[211] Because Ostia was a consumer, and not a producer, site, it needed to be able to store large amounts of food, and its dolia often had capacities of over one thousand liters, far exceeding the dolia of Cosa and Pompeii.[212] Their rims were also standardized, fitted easily with large lids, and were much wider.[213] The rims were so wide, that craftsmen and laborers could easily go inside the vessel for the regular maintenance, cleaning, and repairing of the vessels.[214] Unlike dolium rims at Cosa and Pompeii, the rims of the Ostian dolia were usually more compact with a flat upper surface; this might have been a way for dolium makers to reduce material use in forming the rim while improving the fit between dolium rim and lid (**Fig. 3.40**).


Fig. 3.39. (L) A dolium (no. 67) from Magazzino Annonario (V.11.5).
Fig. 3.40. (R) Example of typical dolium rim at Ostia (Ostia I.4.5, dolium no. 16).

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211 The only dolia that seem larger are those found from shipwrecks.
212 The average wall thickness was 4.82 cm. The range for capacities was 774-1231.4 liters and average was 1,009 liters (including the few anomalous smaller type dolia) or 1,026.3 liters (excluding the smaller dolia).
213 The exterior rim diameter range is 70-102 cm, average 90.8 cm; the interior rim diameter range is 47-73 cm, average 61.9 cm. Dolium lids, found during excavations, are no longer at the site (presumably they are in storage, but no inventory numbers are associated with them); one dolium lid had a stamp (*CIL* 1013). Only one lid is still in a storehouse (Magazzino dei Doli, III 14 3) and has a diameter of 70 cm.
214 Pliny *NH* 14.27; Cato *de Agri Cultura* 2, 23, 45; Columella 12.18.5-7, 12.52.14-17 discuss the necessity to coat the inner walls of wine dolia with pitch and oil dolia with gum. Apuleius *Metamorphoses* IX.5-7 narrates an episode where a man goes into his dolium, which is buried in the courtyard of his house, in order to hack away the vegetation that had grown on the interior wall after a prolonged period of disuse.

While capacity incisions have not been found on dolia at Cosa and almost never at Pompeii, the better-preserved dolia have incisions of Roman numerals on the dolium shoulder or rim, and sometimes both the shoulder and rim, to indicate their capacities in units of amphorae (**Fig. 3.41**).[215] The logistics behind uniformly labeling such detailed vessel capacities, which included fractional units in *sextarii*, suggest that these vessels were measured by filling the vessels with liquids by the amphora.[216] With such large vessels, it was impossible to know or estimate how much they could hold, especially to such a specific degree, based on appearance alone. Since dolia of at least three of the four storehouses were marked with these incisions, it is likely that this systematic method of measuring and labeling dolia became part of the production process.[217]

Fig. 3.41. Capacity incision on dolium rim and shoulder (Ostia I.4.5 dolium no. 12).

The homogeneity of the many dolia of Ostia suggests that here was a development in the craft where workshops were closely aligned and performing the same procedures.[218] The vessels not only had the same forms, dimensions, and types of capacity labels, but almost all

215 And in the case of the Villa Regina dolia at least, the capacities are indicated in units of *urnae* (= 13.125 liters and 0.5 amphora) rather than amphorae at Ostia; the ones at Pompeii are also likely in *urnae*. These capacity incisions will be discussed in more detail in **Chapter 5**.
216 Cf. Gatti 1903.
217 All dolia with their shoulders and rims intact featured a capacity label. It is possible that the warehouses were under the same management, which implemented this labeling system; this possibility, and the incisions in general, will be further discuss in **Chapter 5**.
218 Cf. Taglietti 2015.

were made with clay from the same source (**Fig. 3.42**).[219] Ostia procured some of the largest and most robust vessels from reputable workshops along the Tiber Valley (**Fig. 3.43**).[220] The different dolium stamps, almost none of which feature the same name, point to multiple workshops, with a more complex organization, that supplied dolia to Ostia (**Table 3.6**); the stamps, appearing on c. 20% of the dolia, might have been important branding devices for dolia that were sold in markets and by merchants, rather than ordered at the workshop directly.[221] Stamps contained names of individuals in the genitive or nominative case, and were usually decorated with seal impressions.[222] Names in the genitive case likely identified the owner of the workshop and estate, akin to the *dominus* featured on brick stamps (**Fig. 3.44**). Names in the nominative case, often modified by *s(ervus)* or *ser(vus)* and/or accompanied by a name in the genitive, were usually followed by *f(ecit)* or *fec(it)* to specify the producer of the vessel (**Fig. 3.45**). These individuals, mostly slaves, could have been the dolium makers themselves or, more likely, the *officinatores* since some names have been attested on other *opus doliare* products in the region of Rome.[223]

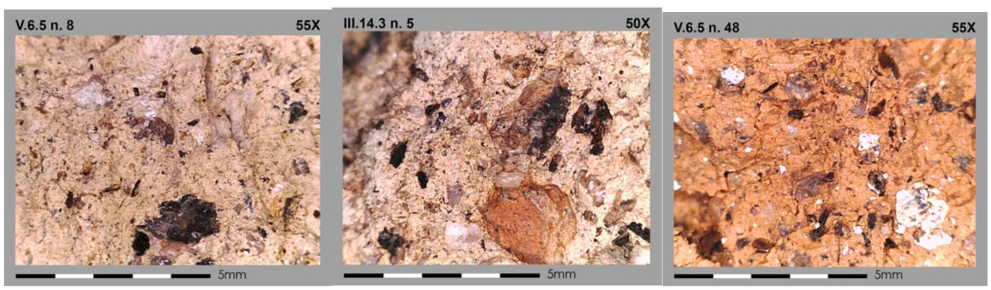

Fig. 3.42. Microphotographs of dolium ceramic fabrics from Ostia; left and center microphotographs are of the most common fabric, fabric on right appears only a few times.

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[219] The ceramic fabric was reddish yellow with sparse black sand and mica inclusions. Almost all the dolia had similar, if not the same, morphology and ceramic fabric, with the exception of just four that were smaller (average rim exterior diameter 67 cm, interior diameter 45.5 cm, average capacity was 808.82 liters, wall thickness 3.0 cm) and had red ceramic fabric.

[220] Although these urban *opus doliare* workshops probably primarily served Rome's markets, the products were probably also distributed further afield, such as the island of Elba (Manca et al. 2016) and even southern Gaul (Carrato 2017, 619).

[221] *Geoponika* 6.3: a customer could test a dolium by the sound it makes when one strikes it, or could go directly to the workshop to examine the clay and vessels. This passage suggests that a dolium buyer could have purchased a dolium directly from the workshop (and those dolia would not need to be stamped) or from a market or merchant (and the stamp would verify the vessel's origins).

[222] The various images are included in Bloch 1948 and the *CIL* entries. It is unclear what their functions were, and whether they conveyed information in additional to other stamps.

[223] It was unlikely that a specialized dolium maker would make bricks or tiles, which did not require skilled labor, especially when these production activities took place the same time (April-October).

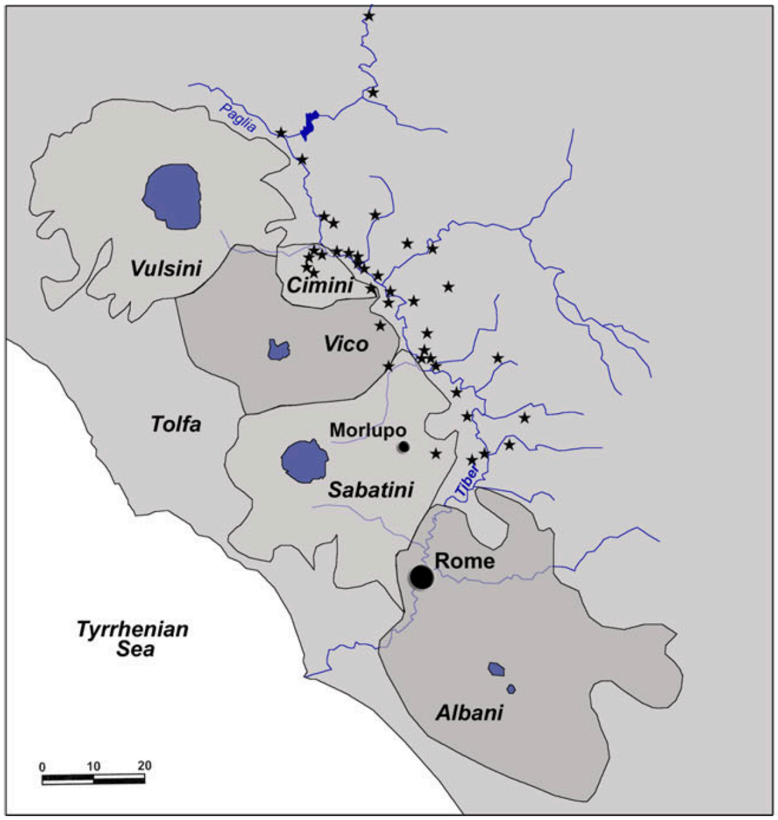

Fig. 3.43. Urban *opus doliare* workshops north of Rome. From Manca et al. 2016.

Fig. 3.44. Stamp on dolium rim (no. 10) from Magazzino dei Dolii (III.4.3): C VIBI FORTVNATI/C VIBI CRESCENTIS.

Fig. 3.45. Stamps on dolium rim (no. 1) in Magazzino dei Doli III.14.3: PYRAMI ENCOLPI/AVG DISP· ARCARI (l) and AMPLIATVS· VIC· F (r).

The occasional overlap between *officinatores* mentioned on dolium stamps and on brick stamps indicates that, by this time and near the capital, dolia were firmly established products of *opus doliare* workshops in the Tiber Valley that also produced bricks and tiles.[224] Some of these individuals were from families who had a hand in industries that supplied various *opus doliare* products to the greater region of Rome as early as the late Republican period.[225] Dolia had already been part of brick and tile production in workshops from earlier periods, but the association between them became closer over time (**Fig. 3.10**).[226] From the production point of view, this made sense. Dolia, bricks, tiles, and other *opus doliare* products have the same ceramic makeup and their materials were prepared the same way. Moreover, if dolium production failed, the materials could be valuable in its reuse (if there were problems before firing) or recycling as refractory material (if it had already been fired) in bricks, tiles, and other *opus doliare* products, cutting down on potential losses.[227] By merging dolium, brick, and tile

224 The literature on *opus doliare* workshops in the Tiber River Valley is vast; cf. papers in Bruun 2005; Bodel 1983; Steinby 1987; Graham 2006; Lazzerretti and Pallecchi 2004; Bergamini 2007; Comodi et al. 2006; Manca 2016; papers in Spanu 2015; Gliozzo 2007.

225 Taglietti 2015 discusses the activities of the Tossius family which was active in the *opus doliare* industry for several generations. Carrato 2017, 619: a dolium with stamp of Q. Tossius Priscus was found in Gaul.

226 In earlier periods, dolia were often produced with any of the following products: amphorae; coarseware pottery; lamps; bricks and tiles; architectural terracottas; etc. Over time, dolium production overlapped more and more with brick and tile production, and less with other products. Cf. Olcese 2012.

227 Nicoletta 2007; Tols and Borger 2016; Olcese 2012 identify multiple dolium production sites with dolium wasters.

production, then, workshops balanced the lucrative, yet risky manufacture of dolium with revenue from the stable, but low-profit bricks and tiles for Rome's architectural projects.

The widespread appearance of these families on stamped ceramic and terracotta products suggests there were significant changes to the industries. Because dolium production was such a difficult and risky activity that required substantial investments, it became an operation that, over time, only large workshops could develop successfully. There were new economies of scale, where these families increased their profits by producing greater quantities of bricks, tiles, dolia, and other heavy ceramic and terracotta products at a lower cost. Their increasing capital probably contributed to the monopolization of ceramic industries as dolium production continued to become concentrated in the hands of fewer, larger workshops owned by wealthy elites. Overall, the additional information found in the dolium stamps at Ostia suggests dolium production had been folded into a system of organization within *opus doliare* workshops and that the stamps were used as markers of quality (a particular and reputable workshop made the dolium) or, more likely, for internal bookkeeping in the workshops (*officinatores* or *doliarii* to record the products they made in addition to labeling the *dominus*).

The numerous *opus doliare* workshops attested on the Ostian dolium stamps combined with the similarity of the vessels point to numerous workshops clustered in the vicinity of the same clay sources producing dolia for Ostia, and probably Rome. Although various workshops, and different *officinatores* and *doliarii*, manufactured these vessels, there was an established and accepted design for dolia that these producers were able to replicate. These workshops invested substantial resources in the craft in order to manufacture large, standardized, and high-quality vessels, and became reliable and reputable production sites. The owners or managers of the *cellae vinariae* at Ostia purchased the vessels from a market or through merchants or were able to able to order and reserve dolia directly at workshops in order to meet the city's storage needs.

3.8 ***Conclusion.*** Large ceramic vessels were traditional storage containers of the Mediterranean, but Roman dolia were incredibly massive vessels with a specific design and purpose, breaking away from earlier storage container traditions in function and scale. The emergence and expansion of a large-scale food supply industry during the Roman period resulted in a substantial increase in both the quantity of foods and the distance they moved across the Mediterranean, and with an ever-improving infrastructure to accommodate this level of trade. Dolia became essential for the production, storage, and transportation of wine, and their production was an integral part of this food supply system. The production of these vessels was, however, unlike the production of other types of packaging containers. It required time, specialized knowledge, and substantial resources and investment. Because it was such an expensive and risky endeavor, the production of dolia for urban settlements increasingly became a commercial activity that gravitated towards the *opus doliare* workshops that would dominate the region by the first century CE. *Opus doliare* workshops were so successful in balancing the risky yet profitable production of dolia with the manufacture of architectural materials, that the advantages of producing dolia in these multi-product workshops led to the workshops' monopolization over dolium production as they were able to increase new economies of scale; over time, these *opus doliare* workshops dominated the Tiber River Valley, and both smaller workshops and independent workshops there lost their foothold in the urban dolium industry.[228]

To design a vessel for wine fermentation and the storage of liquid commodities, dolium makers modified the pre-existing, traditional ceramic storage container; they not only increased the size of the vessel, they also developed a particular shape, outfitting the vessel in such a way that it was optimal for liquid substances. Dolia were round with wide shoulders and a small base. This new strawberry-form facilitated several aspects of dolium use and installation, as well as wine fermentation itself. With its small base and tapering form, it was easier to set or bury the vessel into the ground (for wine dolia); it also enabled the complete removal of the vessel's contents, including old pitch during the regular maintenance and cleaning of the vessel. Beyond installation and maintenance, the dolium's peculiar shape was also conducive to wine fermentation since it stimulated a natural circulation; coupled with the flavor enhancements from the resin coating the vessel walls, the dolium's unique features contributed to creating a particular flavor and texture for wine that the Romans preferred.[229] Dolia therefore became essential fixtures and equipment as the lucrative, long-distance wine trade of west-central Italy grew, and dolium makers continued to develop and refine the craft. Although the sites of Cosa, Pompeii, and Ostia all had dolia, the size, robustness, and quality of these vessels reveal many changes in the industry within a differentiated landscape of production. Dolium production became more sophisticated and successful closer to urban consumer sites, where there were important resources for workshops; the dolia there were larger, more robust, and better fired because they were the products of workshops with the means, and incentive, to develop a sophisticated and lucrative craft.

The settlement of Cosa did not have a large concentration of dolia like Pompeii or Ostia. Most of the dolia from Cosa date to the late second and early first centuries BCE, and were probably used to store bulk quantities of wine produced in the countryside. The dolia were not high-quality products; they were not fired well and probably cracked easily. Based on the range of ceramic fabrics of the dolia, the vessels came from dispersed workshops, which had access to different clay sources. Because the names from the limited number of dolium stamps do not appear among stamped bricks or tiles, it is unclear how specialized these workshops were, i.e. whether they produced dolia exclusively or among other coarseware, brick, and tile products, or whether there was a range in workshop organization; but, based on geochemical and mineralogical analyses done on geo-sourcing of Cosan bricks, there was a minor region of local brick and tile production, in which dolium production might have taken place. Because the dolia were so few in number and relatively heterogeneous, Cosa was not likely the primary market for these vessels; instead, the town may have received second-rate or flawed containers from production batches or had to reserve a dolium at a workshop.

Local specialized workshops supplied the town of Pompeii most of its dolia, while a small portion of dolia came from specialized *opus doliare* workshops further afield in northern

[228] The next stage of this project will study the industries that served the countryside, which may have operated at a different scale and in different ways than workshops that supplied urban centers.
[229] Pliny *NH* 14.27 on the differences between wine made in dolia and barrels. This was also a taste that the Gauls seemed to enjoy as well (Diodorus Siculus 26).

Campania and southern Latium that occasionally competed with local production. The variation in ceramic fabric strongly suggests that there were several small- or medium-scale *opus doliare* workshops, probably clustered around clay sources that supplied dolia to Pompeii. The rims of dolia at Pompeii generally fell within two groups to fit well with standardized inner dolium lids. Dolium makers of the area produced well-made small- and mid-sized dolia, but the quality of large fermentation dolia was more uneven. The large number and overall standardized types of dolia throughout the settlement point to a local production area(s) of *opus doliare* workshops in the vicinity of Pompeii, which not only served Pompeii and its hinterland, but had also mostly aligned their craft practices.

By the second century CE, the urban *opus doliare* workshops along the Tiber River Valley were producing large quantities of massive dolia for the region of Rome; at least two hundred were installed in the storehouses at Ostia alone by the first quarter of the second century.[230] The Ostian dolia were highly standardized in morphology, ceramic fabric, and scale and were exceptionally well made and fired. Although the vessels were from multiple workshops, dolium makers constructed the dolia according to an established design and set of dimensions, including standard rim sizes to accommodate dolium lids likely made by different craftsmen. The dolium stamps indicate that these *opus doliare* workshops not only produced dolia, but also bricks and tiles. Because these *opus doliare* workshops were larger, functioned in an expansive network, and likely had access to more resources including transport along the Tiber River, they had the space, equipment, and materials to manufacture better and grander vessels. Moreover, within an *opus doliare* workshop, different workers could be responsible for the various steps for making a dolium, allowing dolium makers to specialize in the construction of these enormous vessels. Based on the frequency and detailed information of the Ostian dolium stamps, many of the dolium makers and/or *officinatores* were slaves, some of whom were able to rise in the ranks and even be manumitted.[231] Whether those named in the stamps as having made the dolia were dolium makers or *officinatores*, dolium production had become an important industry and probably offered appealing financial and social benefits.[232]

The dense array of the Tiber Valley's large-scale *opus doliare* workshop set-up, which was unparalleled elsewhere in west-central Italy and probably the entire Mediterranean region,

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230 Nicoletta 2007, Comodi et al. 2007: dolium finds from Scoppieto testifies to dolium production from the late Republican period at least into the second century CE; analyses of ceramic fabric confirms that local production of dolia utilized clay sources that were closer to the Umbrian region of the Tiber Valley.

231 A certain C. Vibius Crescens, found on two dolium stamps at Ostia, continued his work in the *opus doliare* industry after manumission.

232 Although unlikely, if the individuals on the stamps were the dolium makers themselves, the employment of many slaves suggests that *opus doliare* workshops needed reliable access to highly skilled labor. The training to become a successful dolium maker was probably restricted to people who had access to the resources and means to complete a length and (unpaid) apprenticeship; most of these were probably talented slaves of wealthy owners (perhaps the workshop owners themselves). For discussion of skilled versus unskilled labor prices in Diocletian's *Price Edict*, cf. Groen-Vallinga and Tacoma 2017; for average time in apprenticeship, cf. Groen-Vallinga and Tacoma 2017; papers in Wendrich 2013. Hawkins 2017: the uneven seasonality of work, especially for agriculture and craft production, meant that having slave labor was a way to ensure a steady and reliable labor supply.

enabled an unprecedented level of dolium production, as well as the growth of a craftsmen's community of knowledge. Artisans were able to share not only materials and equipment, such as clay, water, wood, and large kilns, but also techniques and working knowledge. At production sites near the capital, dolium production became folded into large workshops that also produced bricks and tiles, a low-profit but stable commodity. By the second century CE, members of the sophisticated urban *opus doliare* workshops that produced dolia, bricks, and tile had developed their methods and were able to build massive vessels according to a standardized design; the proliferation and success of these major workshops were so great that the Tiber River Valley had been transformed into a ceramic valley, a hub of ceramic and terracotta production. Building such large vessels, however, was a task fraught with risk, and craftsmen also had to develop new methods in their routines. As this chapter has discussed, dolium makers had to make several significant changes in order to construct such large-scale dolia for the fermentation and storage of liquid products. The next chapter will discuss how dolium makers had to develop and incorporate new techniques in the production of these vessels in order to build large storage vessels that were robust and capable of reliable bulk storage.

Chapter 4 Mending Costly Investments: Dolium Repairs

4.1 ***Introduction.*** Dolia were expensive to make and were expected to last for several decades.[233] But they had one major flaw: they cracked easily. Unfortunately, damage was both undesirable and inevitable. The Latin agronomists mention some of the circumstances in which dolia were subject to breakage; Varro, for example, cautioned that dolia could burst during wine fermentation while Columella noted that dolia could burst when they were cleaned and lined with pitch.[234] But cracks could already start to form during the production process: namely because parts of the vessel dried at different times, with clay naturally shrinking as it dries; it was easy for dolia to crack over the course of their production, which took several days to weeks.[235] Furthermore, the vessel's peculiar shape meant that there were areas of extreme curvature or angles where cracks were even more likely to appear, during both the forming and firing stages. These problems during production, coupled with damage that could occur while they were being used, meant that there were plenty of opportunities for a dolium to crack or break completely.

As with any costly investment, when dolia cracked, it was clearly preferable to repair them than to discard them. But repairing a dolium was inherently difficult. A dolium cannot be taken apart, tinkered with or patched up, and then put together again. In addition, dolia, like other types of pottery, could not be repaired using clay or ceramic materials; making pottery was an irreversible, chemically transformative operation and craft, altering the materials in ways that prevented them from ever bonding properly to clay again.[236] Instead, dolium and pottery repairers had to use other materials and methods to find ways to fill, bind, or anchor damaged areas.

Although repairing dolia was a sensitive and pressing concerning in antiquity, it is rarely discussed in scholarship today. Excavation reports and finds catalogs might describe and report dolia and any repairs that are be found on these vessels, but only a small number of

233 Dolium-like wine vessels still used today, such as Portuguese *tinajas* and Georgian *qvevri*, are used for wine making for at least a couple decades.

234 Varro *de Re Rustica* 1.13.6. Columella *de Re Rustica* 12.18.7. If sealed too early during the fermentation process, the buildup of gas would make the dolium explode. During its maintenance, workers needed to heat the pitch to be able to spread on the dolium wall. A heat source too intense would also cause the dolium to explode. Dolia were covered with an inner lid and an outer lid that offered extra protection; cf. Taglietti 2015.

235 Guven 1993: About a quarter of wet clay is composed of water that exists in three forms, either in 'bound phases' or as 'free phases,' which escape under different circumstances and at different times. ('Free phase' water molecules escaped during the air-drying process, when ceramic objects went from its plastic to bone-dry phase. Chemically 'bound phase' water molecules escaped during firing at about 350-500 degrees C, and was an irreversible chemical transformation.) As clay dries, water evaporates and clay particles are drawn closer together. This results in shrinkage, which can lead to warpage or cracking when the clay dries unevenly. Contemporary potter and archaeologist, Gina Tibbott, estimates a shrinkage rate of 8-10% for heavily grogged clay (these are clays that also consist of ground-up fired clay particles, i.e. reused ceramic products such as discarded pottery or misfired dolia) that was used for the manufacture of dolia.

236 For a succinct overview of transformative crafts, cf. Miller 2009, 103-128.

publications have attempted to address *how* these were made.[237] These notable exceptions include work by Pino Rando, a conservator who worked on materials from the Diano Marina shipwreck, and Theodore Peña, whose work on the life histories of pottery includes a discussion of dolium repairs observed at Ostia and Piammiano; their work substantially advanced, and brought to light, different ways ancient repairers mended dolia. Moreover, Rando's work on the fourteen dolia of the Diano Marina shipwreck, from Albenga (Liguria, Italy) and dated to the mid first century CE, also demonstrated that dolium repairs were sometimes made in the workshop during the *production-phase*. Although repairing dolia involved some of the same considerations and techniques as repairing pottery, there were also significant differences that were unique to dolia and shed light on possible identities of the repairers.

This chapter offers a systematic and comprehensive study of dolium repairs from Cosa, Pompeii, and Ostia, including their materials and methods, and the dolium repair industries of west-central Italy.[238] In fact, the number of repaired dolia is staggering and allows us to shed light on the circumstances and methods of the repairs and even on the people who made them, bringing into view the repairers' major innovations and the repair practices surrounding this valued craft good. This chapter takes stock of the different kinds of repairs for damage that dolia suffered at various points in their production-phase and use-life by examining the range of dolium repairs at Cosa, Pompeii, and Ostia. The discussion moves beyond the physical remains to explore what, in general, we can learn from these kinds of repairs about not only the life histories and trajectories of dolia, but also who repaired them and how they developed their techniques and expanded their community or network of knowledge.[239] The chapter shows that the urban dolium industry serving the area of Ostia (and Rome) developed new and different methods to mend dolia, merging the production and repair of dolia as activities *opus doliare* workshops mastered. But before we can begin, it will be useful to review the different types of pottery repairs and dolium damage and the methodology employed in this analysis.

4.2 *Pottery Repairs and Dolium Damage.* In pottery manufacture, it was inevitable for a portion of a batch of pottery to break or crack, especially during the firing process. Only rarely was pottery damaged during the production process repaired; because most pottery was so cheap, defected pottery was sold at a discounted rate or merely discarded.[240] The majority of repaired pottery we have from antiquity was therefore mended

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237 Rando 1996; Peña 2007a, 37 on dolium manufacture; Peña 2007a, 213-227 on dolium repairs.

238 In addition to Rando 1996 and Peña 2007a, Carrato 2017, 177-180 briefly surveys dolium repairs in Gaul.

239 For recent work on knowledge networks, cf. Rebay-Salisbury et al. 2015. See also discussion on cross-craft interactions in Miller 2007, 237-245.

240 De Caro 1994, 179 n. 151; Peña 2014, 5ff: an African cookware lid (Hayes Form 196) with a production defect, which formed during the firing process, was still sold and then used at Villa Regina at Boscoreale. Peña 2007a, 235: although people might have chosen to repair pottery damaged during the production process or in the course of transportation and distribution, the repairs' labor-intensive nature and the low value of the pottery suggests that most pottery repairs were probably made during their prime use context.

during use. Surviving ancient pottery repairs usually consisted of lead elements to fill cracks or anchor and brace fragments.[241] Lead offered several distinct advantages. It was widely available and inexpensive in antiquity.[242] It is a stable material and has a low melting point (327.5 C) too, so it is easy to work and was probably a material almost anyone could use.[243] To fix cracks and reattach fragments, pottery repairers regularly formed clamps, though they occasionally used staples or fills (**Fig. 4.1**).[244] Forming clamps and staples required some expertise and special tools: the repairer would drill, probably with a bow drill, one or two sets of holes on either side of the crack, introduce metal pins or legs into the holes, and then join them to a crosspiece on one side to form a staple, or on both sides of the vessel wall to form a clamp; the lead elements were probably made in a mold to control the lead and form consistent pieces.[245]

Fig. 4.1. Damaged Gallic sigillata vessel from Wroxeter, repaired with lead clamps.

241 Bentz and Kästner 2006, Peña 2007a, and Lawall and Lund 2011 provide useful overviews of pottery repairs.
242 Lead was a by-product of silver mining. For study on high levels of mining activities during the Roman period, cf. Hong et al. 1994.
243 Due to its low melting point, lead could only be applied to a vessel *after* it had been fired in the kiln.
244 For discussion on Roman pottery repairs, cf. Peña 2007a, 232ff. There is a discrepancy between terms employed for ceramics and architecture. In architecture, a joint is a meeting between two materials, whereas a clamp is a third element (usually a different material) that connects two pieces. There are many different terms used in discussing repairs on pottery, including staple, clamp, rivet, hole and clamp, etc. In architecture and civil engineering, pi-clamps (or cramps) are metal bars with bent edges for holding together building stones or for fastening them to a steel or concrete beam, whereas double pi-clamps are placed on both sides. This study will employ the term 'staple' but it should be understood they are the same as the architectural pi-clamps (or cramps), and 'clamp' instead of double pi-clamp. I thank Lynne Lancaster for discussing this with me.
245 Rotroff 2011, 122; Peña 2007a, 239 convincingly demonstrate that certain uses of lead required certain methods and equipment, in particular with forming clamps, which may have required forming a lead putty, using a mold, or constructing the pieces separately.

Dolium repairs, however, differed from non-dolium pottery repairs (henceforth referred to as "pottery repairs" for ease of discussion) in several substantial ways. The nature of damage on dolia differed from all other kinds of pottery. The first thing that one has to understand about dolia is that they often cracked in the course of the manufacturing process, *before* they were ready for use. Because dolia were coil-built over the course of several days or even weeks, dolia tended to develop cracks of two different kinds during the manufacturing process. The first of these were horizontal cracks that formed along the juncture between two coils – a natural point of weakness – in a phenomenon referred to as a coil fracture (**Fig. 4.2**). The second were vertical cracks that ran downward from the vessel rim known as dunting cracks (**Fig. 4.3**). These formed due to the fact that the rim, as the terminal point and thus the most exposed portion of the vessel, tended to shed water and shrink more rapidly than did the vessel's neck and shoulder during the firing phase of manufacture.[246] Furthermore, dolium repairs often required additional tensile strength to support the heavy and bulky fragments.

Fig. 4.2. Horizontal cracks forming between coils of dolium (I.22 n. 5), Pompeii.

[246] Hamer and Hamer 2004, 119-122: dunting cracks occur due to silica inversions at 573 C and 226 C; this happens during firing, most frequently during the cooling phase. White 2016, 122: a Georgian qvevri maker said about his wares, "If it cracks horizontally, then the error is in my building; if vertically, then the fault is in the firing."

Fig. 4.3. Dunting on rim repaired with lead double dovetail, (III.14.3 n. 1), Ostia.

Although pottery repairs were typically made of lead, by itself lead often did not lend enough mechanical support to dolia; instead, some dolium repairers mixed or combined lead with stronger metals (probably tin, copper, or iron). Working with these metals, however, required both high temperatures, which could only be achieved with a proper furnace and using fluxes, and the expertise of a metallurgist.[247] Forming dolium repairs with stronger materials, then, required additional skills, materials and equipment, and cost, and probably took place during the dolium's production, when the dolium was in the workshop.

In addition to traditional pottery repair methods – staples and clamps – dolium repairers adapted methods from other crafts because staples and clamps were not always the best solution. While pottery menders repaired pottery with lead staples or clamps, these might not be effective on a dolium and could even damage it further. To form a clamp required drilling through the vessel wall. For dolia, forming these repairs risked damaging the dolium further for a repair that might not have been particularly effective on a big, bulky vessel (**Figs. 4.4-5**). Because dolia had thick walls and a coarse ceramic body with large inclusions, drilling could dislodge or displace an inclusion and cause additional cracks. Furthermore, the crosspieces of clamps and staples sat on top of the vessel's surface, presenting a c. 1.5 cm high target for dolium users to strike accidentally and remove. Forming a clamp, even if successful,

[247] Rehder 2000, chs. 11-14.

meant that the vessel might not be liquid-tight since it had holes drilled through its walls.[248] Furthermore clamps posed a particular problem with the routine maintenance of wine dolia: in removing residual pitch lining, which requiring using a heat source such as a torch to melt the pitch, the lead clamp could accidentally be melted off too since lead's melting point was so low. Thee might have been some of the reasons and motivations why dolium repairers experimented with different materials and methods, forming various hybrid methods, but these use repairs were still problematic. To fix dolium damage well, then, repairers had to come up with something else.


Fig. 4.4. (L) Crack that formed at clamp pin hole on dolium (I.22 n. 18), Pompeii.
Fig. 4.5. (R) Profile view of crack that formed at clamp pin hole on dolium, (I.22 n. 18), Pompeii.

4.3 ***The Repairers.*** To have a fuller picture of how dolium repairs were made, it is important to know more about the tools, procedures, and skills of the repairers, and the repairers themselves. Yet almost nothing is known about the different craftspeople who repaired dolia. We almost never encounter these workers in textual sources and subsequently never even begin to consider who these menders might be. But every repair had to be made by someone.

Most of the insights on the dolium repairers and their industries come directly from the archaeological evidence, but several come from other sources of information. A handful of ancient texts briefly mention the use of organic fibers or lead to mend the cracks; Varro briefly mentions repairing dolia by binding dolium fragments with rushes, whereas Juvenal describes any damage to the dolium abode of Diogenes the Cynic as being repaired with

[248] The lead clamp would also probably have some contact with the dolium's contents, potentially affecting their taste and quality, although Romans occasionally heated wine in lead containers to sweeten the wine.

lead.[249] The most informative passage, however, is Cato's detailed passage about mending dolia in his agricultural treatise:[250]

> Ubi tempestates malae erunt, cum opus fieri non poterit, stercus in stercilium egerito, bubile, ovile, cohortem, villam bene purgato; dolia plumbo vincito vel materie quernea vere sicca alligato. Si bene sarseris aut bene allegaveris et in rimas medicamentum indideris beneque picaveris, quodvis dolium vinarium facere poteris. Medicamentum in dolium hoc modo facito: cerae P. I, resinae P. I, sulpuris P. C' C'. Haec omnia in calicem novum indito, eo eddito gypsum contritum, uti crassitudo fiat quasi emplastrum, eo dolia sarcito. Ubi sarseris, qui colorem eundem faciaem cretae crudae partes duas, calcis tertiam conmisceto; inde laterculos facito, coquito in fornace, eum conterito idque inducito.
>
> When the weather is bad and no field work can be done, shift dung to the dung-heap; clean out the ox shed, the sheepfold, the hen-run, the farm buildings; mend wine vats with lead, or bind with sappy oak stems. If you mend or bind them well, fill the cracks with putty, and pitch well, any vat can become a wine vat. Make up putty for wine vats as follows: 1 lb. wax, 1 lb. resin, 1/3 oz. sulphur. Put all together in a new saucepan, add powdered gypsum till it reaches the consistency of a plaster. Use to mend vats. After mending, to make all the same color: mix two parts raw clay with a third part lime. Make small bricks book in the oven, grind and apply.[251]

This passage presents a rare picture of this activity and highlights that, during the second century BCE, farmhands were expected to repair damaged dolia, especially when they could not work outdoors. The process of repairing dolia when they were damaged while in use was not simple. Peña notes the different steps Cato outlined:

> From this passage it can be inferred that for the repair of a cracked or broken wine dolium Cato envisages a procedure consisting of a sequence of four operations:
>
> 1. Bracing the vessel by means of elements of some sort fabricated either of lead or dried oak;
> 2. Filling the cracks with a compound consisting of a set ratio of wax, resin, and sulfur, and a variable amount of gypsum;
> 3. Matching the color of the repair to that of the vessel by coating the repaired area with a compound consisting of a set ratio of clay and lime that have been heated and then pulverized;
> 4. Pitching the interior surface of the vessel.[252]

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249 Varro *De lingua Latina* 5.137; Juvenal *Satura* 14.308-310; discussion in Peña 2007a, 215-216.
250 Cato *de Agri Cultura* 39.
251 Latin text and translation from Dalby 1998.
252 Peña 2007a, 214.

Cato seems confident that dolia, even broken ones, would be made suitable for wine. Although both Cato and Varro mention using organic material to bind the dolia, no material evidence supports this. This practice of using organic material to repair dolia might have been used in Italy during the final two centuries BCE, and simply did not survive in the archaeological record, but it is more likely that these passages were from a period before which repairing dolia became a specialized task, perhaps even of a specialized industry.[253]

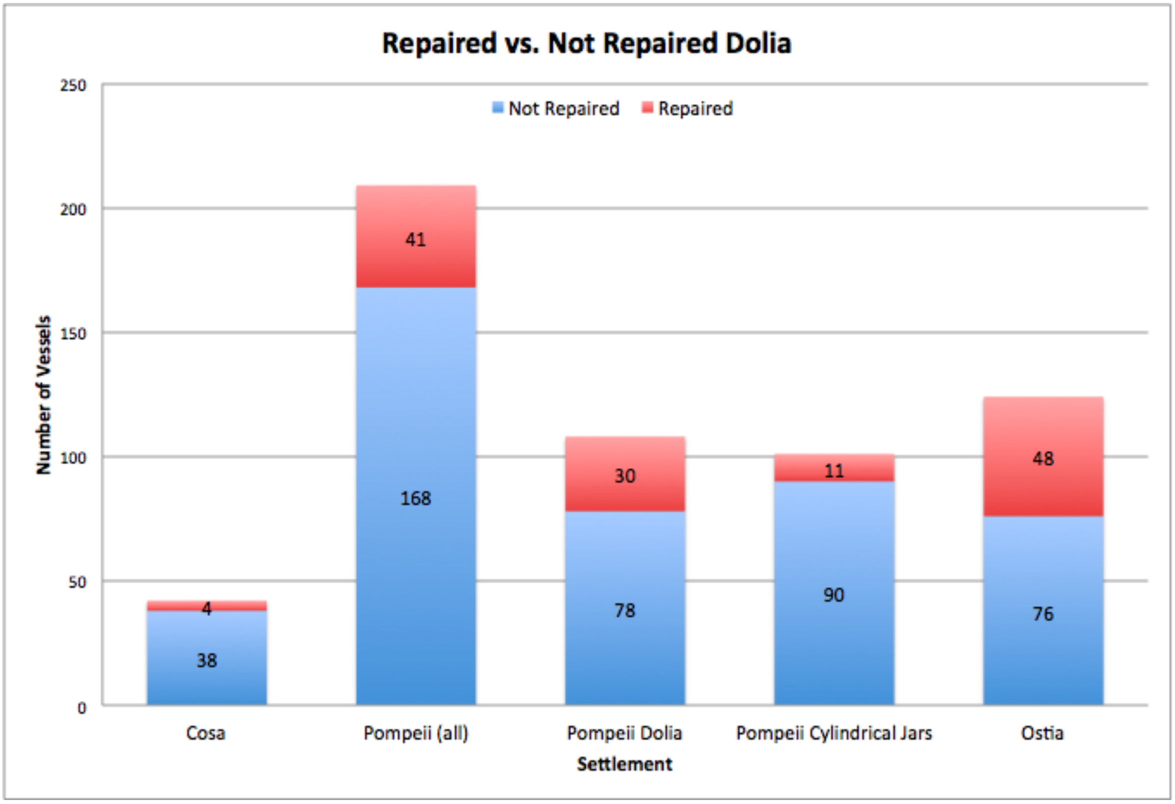


Fig. 4.6. Proportions of repaired dolia (and other storage vessels) at Cosa, Pompeii, and Ostia.

Examples of traditional pottery repair from more recent, and well-documented periods also provide useful insights to the industries involved for the repairs of these vessels. In different pre-industrialized societies, specialized pottery menders set up repair stations in cities and towns, such as Paris and London, whereas rural itinerant repairers made through rounds through the countryside to offer their services to potential clients.[254] For example, in Luigi Pirandello's early 20th century work, "La Giara," Don Lollò Zirafa, a *padrone* (wealthy landowner) in rural Sicily hires an itinerant repairman to fix his broken olive oil storage jar, which is similar in size and shape to the dolium. The repairman carried his kit of tools and materials with him as he traveled through the country, climbing into the vessels to form the

253 Peña 2007a, 227 suggests that there could have been a development in dolium repairs, from farmhands mending the vessels with organic fibers during the time Cato wrote *de Agri Cultura* to the emergence of a specialized repair industry that used lead by the first century BCE.
254 Cf. Thornton 1998 for overview of porcelain repair and its industries; Albert 2012, Garachon 2010 on riveting techniques in mending porcelain.

repairs. In a different part of Europe during the sixteenth to eighteenth centuries, porcelain was a high-value, exotic commodity. Because it was considered a precious and collectible commodity that was expensive and difficult to acquire, its repair became an important occupation and emerged as a separate industry, with repair specialists who worked entirely independently from the porcelain production industries. In cities, porcelain repair was usually done by specialized workshops or by repairmen who set up workstations in heavily frequented areas, while itinerant repairers served the countryside. Ethnographic examples cannot tell us what happened with dolia in antiquity, but they demonstrate at least two things. First, it is possible that different types of repairers worked in urban compared to rural areas, with specialists who set up stations in cities and non-specialists, such as tinkers, who served the countryside. Second, the repair of an object can be entirely separate from its production, and two craft specializations for pottery, one for its production and one for its repair, could emerge. Pottery and dolia were, therefore, particular kinds of craft goods that, if they were damaged during normal use, were repaired by craftsmen who had nothing to do with the manufacture and instead had their own sets of equipment, skills, and techniques. Textual sources and ethnographic examples are helpful in urging us to shift perspectives and consider different possibilities, but the numerous dolium repairs have much to tell too (**Fig. 4.6**).

4.4 *Methodology.* The following sections examine the numerous dolium repairs at Cosa, Pompeii, and Ostia, with a focus on: the dolium repair technique; the material of the dolium repair; and when the repair was made. Repairs generally involved two kinds of elements: fills and bracing elements. Fills served to infill cracks or, in some cases, gaps in a vessel wall extending over a large area, ideally rendering the repair vessel liquid tight (**Fig. 4.7**). Bracing elements limited the propagation of cracks and/or solidified the repaired vessels, and were made in various configurations. They include *staples* and *clamps*, as discussed briefly under pottery repairs, which involved using a bow drill and molds, likely premade ceramic molds, to form staple-shaped metal bars over the break (**Figs. 4.8-9**). These were traditional pottery repair techniques typically used when the vessel was damaged during its use-life. There were also dolium repairs of different techniques (*double dovetail clamps*, *double dovetail tenons*, and various *hybrid* repairs that combined different techniques), which I will present and analyze in greater detail in the following sections.

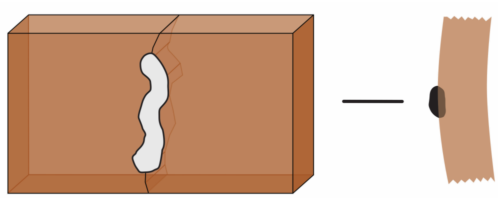
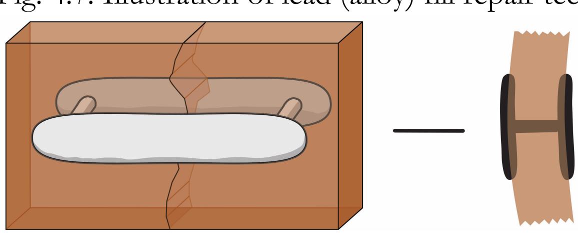


Fig. 4.7. Illustration of lead (alloy) fill repair technique, by Gina Tibbott.



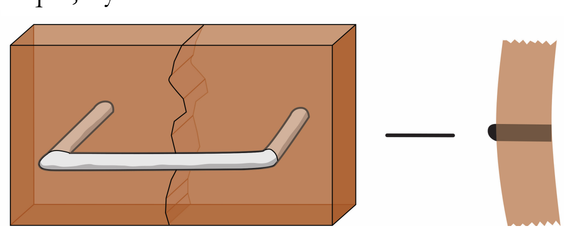


Fig. 4.8. (L) Illustration of clamp repair technique, by Gina Tibbott.
Fig. 4.9. (R) Illustration of staple repair technique, by Gina Tibbott.

I also studied the repair's material and determined whether a dolium repair was made of lead or a combination of lead and another metal on the basis its color. Oxidized lead corrodes at a very slow rate and has a distinctive white or white-gray surface (**Fig. 4.10**). This is the most common metal used in the repairs, but occasionally repairers combined lead with another metal to strengthen the repair, resulting in a dark (grayish) brown, dark gray, or dusky red surface (**Fig. 4.11**). Tin is most likely the metal that repairers used to strengthen lead. Tin has a workable metal point (232 C) and is a strong metal; its brittleness decreases when paired with lead.[255] Interestingly, the terms *cassiterum* in Latin and κασσίτερος in Greek mean "a mixture or alloy of lead, silver, and other metals, afterwards tin" (*TLG*). The Greek term is related to the word for "tinker," suggesting tinkers used a lead alloy, possibly mixed with tin, and one proposed etymology for "tinker" also attributes it to the word "tin."[256] Without scientific analysis, specifically compositional assaying, it is impossible to identify securely the other metal(s) used in the lead alloy, so it will be referred to as lead alloy. Even though it can be challenging to distinguish the metals used in the lead alloys, it is important to make the distinction between *lead* and *lead alloy* because the expertise and access to these materials often differ and can potentially tell us about who might have undertaken the repairs.[257] Using lead did not require specialized skills or equipment, whereas preparing and working lead alloy did and probably took place in a fixed and properly equipped workspace.[258]


Fig. 4.10. (L) Lead repairs on dolium rim and shoulder (Villa of the Mysteries n. 3), Pompeii.
Fig. 4.11. (R) Lead alloy clamps on belly of dolium exterior wall (II.8.6 n. 1), Pompeii.

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255 Slane 2011: at Corinth, a *pithos* was repaired with a clamp that had small amounts of tin and iron. Giardino 2012: a dolium at Metapontum was repaired with lead and traces of tin and copper.

256 Another possible metal for the alloy is copper, which was occasionally combined with lead to form architectural clamps; cf. Cooper 2008.

257 It is not possible to identify the other metals used in alloys without scientific analyses, but I have initiated a collaborative study with a chemistry laboratory at the Università degli Studi di Napoli Federico II in Naples to identify metals in dolium repairs.

258 Cf. Brun et al. 2005 for discussion of a lead workshop found at Herculaneum.

Sometimes it is possible to determine *when* certain dolium repairs were made based on their physical characteristics. In the case of repairs made *after* the vessel had been fired (often referred to be archaeologists as *post-cocturam*), any cuts made into the vessel are apt to display irregular, generally rough or chipped edges; when securely identified, these use-life repairs are designated as *use repairs* (**Fig. 4.12**). Although almost all other pottery repairs were made while the vessels were in use, Rando, in his analysis of the dolia from the Diano Marina shipwreck, noticed that the cuts in the vessels displayed a distinctly crisp, regular edge, and he reasoned and then confirmed through experiments that these incisions must have been made prior to firing, presumably when the vessels were in the green or leather-hard stage.[259] Repairs that have crisp, regular edges were therefore carved or drilled *before* a dolium was fired; when securely identified, these production-phase repairs are called as *production repairs* (**Fig. 4.13**). Sometimes the stage in which a dolium repair was made is *unknown*, while some dolia feature repairs made *both* during production and then again during use.

Fig. 4.12. Lead double dovetail made during *use* (Villa of the Mysteries n. 3), Pompeii.

[259] Most dolium repairs were assumed to have been made during the use-life of a dolium, but Pino Rando 1996 conducted a series of experiments to reproduce the repairs and found that the neat double dovetails and double dovetail tenons had to have been cut into the vessel's surface before it was fired in the kiln; and the lead (mixture) was added to the cuttings after firing.

Fig. 4.13. Lead double dovetail tenons made during *production* (I.22 n. 3), Pompeii.

The dolium repair type, material(s), and stage of execution often provide important clues regarding the likely identities of those who carried out the repairs. Although we cannot say who *exactly* made the dolium repairs, we could at least narrow the range of possibilities by distinguishing the requisite craft skills for the repair, when and where the repairs were made, and the frequency and intensity of the task. For example, a production repair meant that the repair was made in the workshop, and was therefore the handiwork of a craftsman there or an outside, specialized craftsman commissioned for the task. Even if some dolia were made and repaired by itinerant potters, the same personnel was making the repairs. On the other hand, demand for the repair of dolia that broke during use would have been irregular, involving a much wider array of personnel. Different craftsmen could have been recruited to form use repairs, and often these craftsmen had no part in the production of these vessels. In examining the different dolium repairs at the three case study sites, the repair technique and material, and when it was made, shed light on the skills, materials, and potential identity of the repairer.

We have evidence for the repair of dolia that extends from the earliest period of their manufacture through to the end, demonstrating that interventions of this kind were considered a worthwhile endeavor. Repairing dolia presumably allowed the owners of these costly vessels to retain their value as storage containers rather than repurposing or discarding them. As we will see, dolia were repaired with a range of methods and materials throughout west-central Italy from the second century BCE to at least the end of the second century CE. By distinguishing the dolium repairs at Cosa, Pompeii, and Ostia, however, we can see that the methods and materials for mending dolia were not static or fixed. The analysis of the dolium repairs attested at these three sites indicates geographical and diachronic variability in the techniques employed, while also pointing to differences in the identities of the craftsmen who undertook this work.

4.5 ***Cosa.*** The dolia of Cosa are mostly dated from the late second century BCE to the first century CE and some (c. **10%**) were repaired with wildly different methods, resulting in varying degrees of success (**Table 4.1**). I examined a total of five dolia that had been subject to repair; with the exception of one, all the repaired dolia from Cosa were found in discard, rather than use-related, contexts, so we are not in the position to know more about the background of their repair and (re)use. Almost every repair used only lead, which did not offer much structural stability or support. The repairs, all of which appear to have been made during the vessels' use, display various kinds of irregularities that suggest that those who executed them did not possess a high level of expertise in these types of operations.

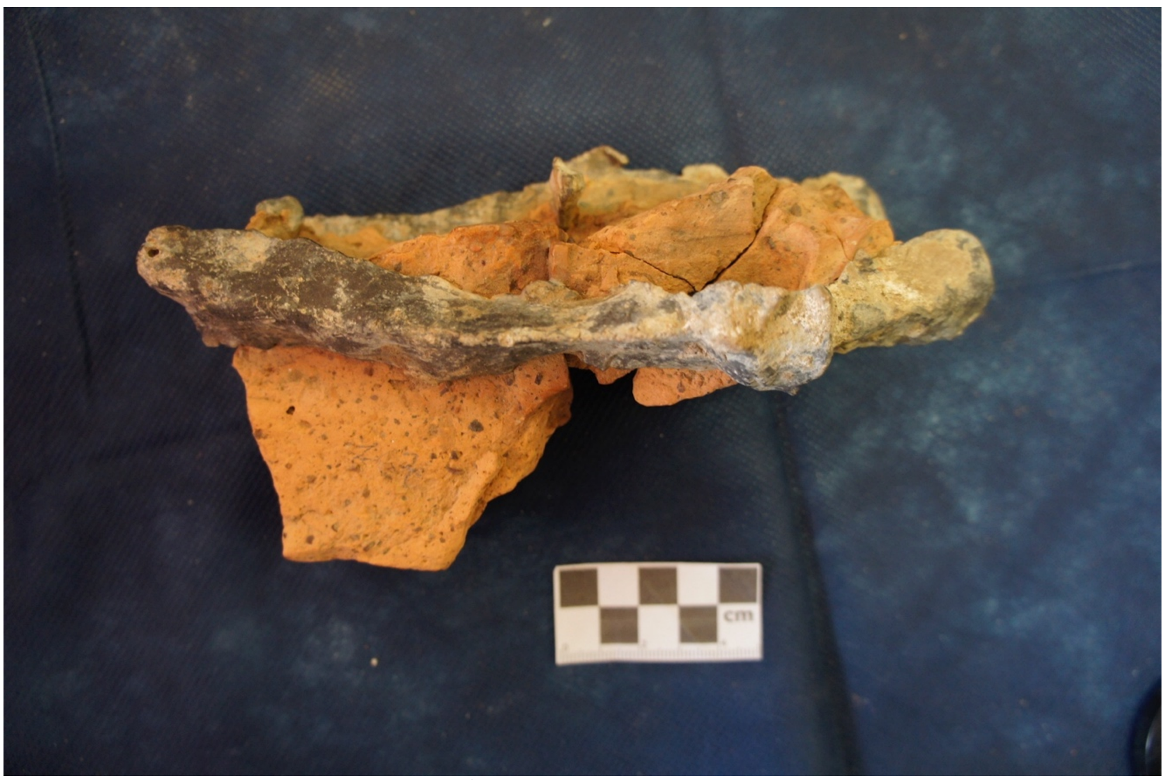


Fig. 4.14. Profile view of clamp on a dolium fragment (Cosa n. TC), from Cosa.

Some of the repairs are closely aligned with the methods used on smaller types of pottery, clamps (**Fig. 4.14**). But repairers probably noticed the shortcomings of clamps, i.e. drilling into a dolium could result in more damage to the vessel, and instead sought to improve their techniques.[260] One way was to combine two different methods, the traditional pottery mending clamp and a different type of technique that was used in architecture, the

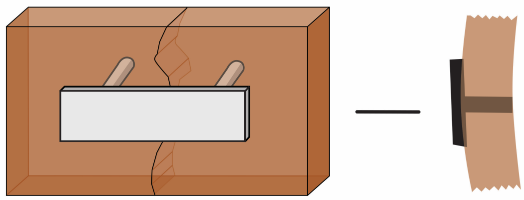
[260] Davis 2000, 12, 284-287.

mortise-and-tenon, to form a type of *hybrid* repair. Since the mortise-and-tenon was uncommon in repairing ceramic objects, it will be useful to review this technique so we can understand its significance for dolium repairs more generally.

Fig. 4.15. Mortise-and-tenon staple (metal missing) on architectural stone block, in Bass Garden of the American Academy in Rome.

The mortise-and-tenon technique is a traditional type of joinery widely found in carpentry and architecture; pieces of wood are joined by fitting together a mortise hole with a tenon, which would be cut specifically to fit into the mortise.[261] Builders and pottery menders adopted and adapted the technique for their media. To form it on stone, builders carved or chiseled a rectangular slot into the surface, drilled two pin holes near each end to form the mortise, and set the lead or lead alloy into the slot and pin holes to form the tenon (**Fig. 4.15**). Dolium repairers used these hybrid mortise-and-tenon staples (*MTS*) or clamps (*MTC*) in an attempt to provide additional strength to their repairs (**Figs. 4.16-19**). But they also began to modify and further improve these hybrid repairs with a specific, more effective type of mortise-and-tenon known as the double dovetail.

261 The mortise was the slot into which the tenon was fitted; for buildings and ceramics, the mortise was the slot that was cut or chiseled into the surface, and the tenon was what filled it; this would be known as a type of pi-clamp in architecture. Bilde and Handberg 2012, 464. Ulrich 2007, 61-64: mortise-and-tenon joints, albeit a different variation, were found during the last phase of the second millennium CE at Stonehenge. Adam 2005, 96. Ulrich 2007, 61ff. discusses different types of mortise-and-tenon joinery techniques found in Roman carpentry and other types of construction.



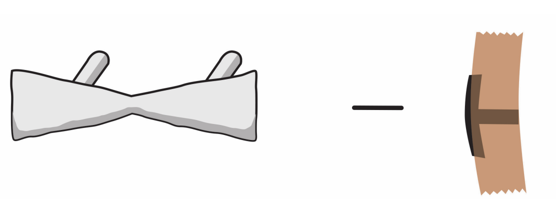


Fig. 4.16. (L) Illustration of mortise and tenon repair technique, by Gina Tibbott.
Fig. 4.17. (R) Illustration of double dovetail mortise and tenon technique, by Gina Tibbott.

Fig. 4.18. (L) View from above of lead clamp on dolium shoulder (Cosa n. 19), Cosa.
Fig. 4.19. (R) Profile view of lead clamp on dolium shoulder (Cosa n. 19), Cosa.

In carpentry, dovetail mortise-and-tenon joints were the traditional joinery technique not only in case-piece construction for items such as boxes, dressers, and other furniture, but also in shipbuilding and temple construction.[262] Cutting dovetails in wood, however, differed from how craftsmen formed dovetails on other materials.[263] Although this technique became

262 For discussion of use of double dovetails and how a carpenter would form them, cf. Korn 2003, 106ff. Evidence of Roman carpentry generally only survives in extremely arid environments or in waterlogged contexts. Construction workers used wooden double dovetails to hold stone blocks in place during the construction of the Forum of Augustus (Ganzert 1996, 124).

263 Dovetail joins in woodworking required cutting single dovetails in a highly precise manner on the ends of the wooden boards, i.e. the carpenter had to cut dovetails on the edges that would contact one another; both the mortise and the tenon had to be fabricated from wood. For more detailed discussion and images of the process, cf. Korn 2003, 106ff. Korn 2013, 94: mastering the technique of cutting mortises and tenons in woodworking required not only mastery of the various tools, but also knowledge of "wood strength, wood movement, grain direction, and properties of adhesives." Double dovetail mortises on stone and ceramic surfaces, on the other hand, were cut or chiseled on the surface, and then filled with a metal to form the tenon; often these metal tenons were either a) mold-made tenons that were hammered into the mortise, or b) the metal was applied, in a malleable or liquid state, directly into the mortise.

important for ashlar masonry, builders adapted the technique several times.[264] Some of the earliest evidence for double dovetail tenons for architecture involved placing the wooden double dovetails to clamp stones in pharaonic Egyptian structures. Greek craftsmen also used wooden double dovetail tenons, but they formed a faster, less precise method by regularly using pre-fabricated mold-made tenons made of lead, and occasionally copper, which they then hammered into mortises, a method Roman builders also used (**Fig. 4.20**).[265]

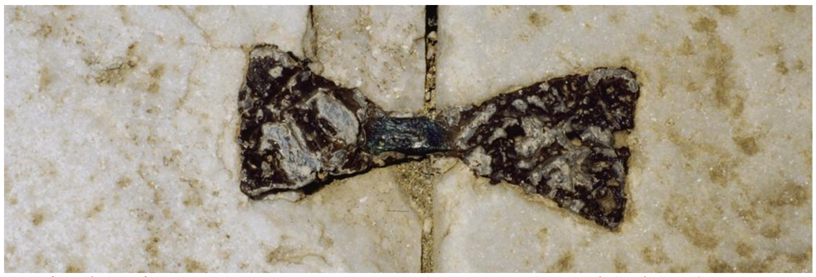


Fig. 4.20. Bronze double dovetail joining two architectural marble blocks at Delos.

By the time pottery and dolium menders became familiar with this technique, it had already evolved through two different crafts, before they adapted it to incorporate it into their repertoire of repair techniques to mend ceramic and terracotta objects. The rare instances in which double dovetails were used to repair small, fineware pottery involved scratching away only a small amount of ceramic material from the surface to form the mortise into which lead would be added (**Fig. 4.21**).[266] For joining thick dolium fragments, the double dovetail was an effective shape that prevented the wider end of the mortise (the two ends of the double dovetail) from withdrawing. It acted as both an anchor and a fill. At Cosa, dolium repairers both drilled into the vessel wall and chiseled a double dovetail shape into the vessel surface to harness the double dovetail technique to augment clamps (*DDC*) and staples (*DDS*) on a dolium base and dolium shoulder (**Figs. 4.22-23**). One dolium repaired with this method, however, featured a double dovetail (*DD*) *without* a staple or clamp, suggesting that the double dovetail method was considered effective on its own (**Figs. 4.24-25**). Forming a double dovetail without a staple or clamp also meant that the repairer no longer relied on molds to control the lead, but had to modify the material and/or refine the technique.[267] Controlling the

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264 Ural and Uslu 2014 discuss the effectiveness of different types of and differently positioned metal connectors under shear stress.

265 Lugli 1957, 239: iron pi-clamps, and rarely T-clamps, encased in lead appeared in Roman architecture around the end of the Republican period. Adam 2005, 96-100: pi-clamps were particularly popular in Roman architecture. T-clamps required more time, effort, and precision to fashion the iron T-clamps and to cut the holes into which the clamps would be placed.

266 Of the 35,000 ceramics vessels Rotroff 2011 examined, 160 were repaired and only eleven had the mortise-and-tenon technique. Peña 2007a, 246ff also notes that double dovetails rarely occur on Roman pottery, with perhaps only 1.1% of pottery from the Museum of London collection featuring this form of repair. Dooijes and Nieuwenhuyse 2007 describe different types of repairs found on Greek pottery; Bilde and Handberg 2012. Peña 2007a, 228-249.

267 On putty in repairs, see Rosenfeld 1965, 139-141; Thornton 1998, 11; Peña 2007a, 220ff. I thank Lynne Lancaster for sharing video documentation of her experiment with pouring lead, which demonstrated how challenging it can be to work with molten lead.

flow of molten lead or lead alloy would have been difficult, particularly as the fabrication of many of the elements, if it involved using them in a liquid state, would have required the execution of pours along a curved surface, and those who carried out these repairs must have developed methods of overcoming this problem. Repairers could have added linseed oil to form a putty or used a lead-tin alloy. They could have moved the vessel to direct the flowing lead if the area being repaired was small, but this was probably not particularly effective.

Fig. 4.21. Damaged fineware repaired with lead double dovetails, Marseille History Museum.

Fig. 4.22. (L) Lower wall and base with lead clamp on dolium base (Cosa, n. 29).
Fig. 4.23. (R) Underside of base with half of lead double dovetail preserved (Cosa n. 29).

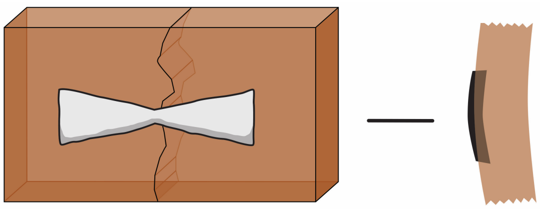

Fig. 4.24. (L) Illustration of double dovetail repair technique, by Gina Tibbott.
Fig. 4.25. (R) Dolium rim, partly preserved double dovetail labeled (Cosa n. 1), Cosa.

Beyond these methods, some dolium repairers instead drew on different joining techniques. Two dolium rims were modified and repaired with iron nails or pegs that were drilled in and connected by a thin strip of lead, a technique is parallel with architectural dowels, where marble and stone workers often encased iron rods or bars in lead to join segments in sculpture or column drums to provide both vertical support and binding between pieces (**Fig. 4.26**).[268]

Fig. 4.26. Three iron screws and thin strip of lead on dolium rim surface (Cosa n. 1), Cosa.

Every preserved dolium repair at Cosa was different and featured methods and materials also employed in pottery repairs. The fact that the repairs documented at Cosa each differ from one another in significant ways suggests that there was no widely accepted set of methods for the execution of operations of this kind in the town; this raises the possibility that these repairs were carried out on an adventitious basis by individuals with widely varying levels of skill and areas of expertise, rather than by an established set of craftsmen who undertook this kind of work on a regular basis. Although we cannot determine who exactly these repairers were, we could at least tease out some of the salient skillsets involved to better understand their possible occupations. Some of the dolium repairers drew from and combined

[268] For an overview of this technique to join statuary, cf. Claridge 1990; Wootton et al. 2013.

the existing repertoire of repairs found on smaller pottery to form clamps. These could have been the handiwork of pottery menders or tinkers, who were itinerant, non-specialist repairers. I include pottery menders and tinkers as a group of possible repairers who mended dolia during their use-life, but, to my knowledge, there is no Latin word for 'pottery mender' or 'tinker.' On the other hand, there was an occupational title for 'mender of bronze vessels,' *refector ahenorum*, and there is a Greek word for "tinker," κασσιτερᾶς (*BGU* 9 IV 22 1087).[269] Tinkers provided important, but perhaps informal or unofficial, services and were not necessarily fixtures in a community, and were therefore likely not well-attested in either the material or text record.[270] On the other hand, the repairs using double dovetails were formed with knowledge from the architectural realm to join stone blocks and drums. This can be seen in the construction of baths, where technical knowledge in vaulting techniques spread for building baths and there were increased interactions among builders, terracotta workers, and potters, including the use of particular tools. Furthermore, tile workers likely adapted the use of lead clamps on terracotta bars from potters and repairers who used them to mend amphorae and dolia.[271] These repairs might have been formed by construction workers, builders, or joiners who worked on architectural projects in Cosa.[272]

Overall, the limited number of dolia at Cosa also meant that this was not a region where repairers had opportunities or need to experiment with or develop dolium repairs, or to exchange ideas with each other; instead, various kinds of craftsmen for whom work of this kind probably represented only a minor sideline, including perhaps stone masons, smiths, and/or tinkers, visited the town to make a repair, each using his or her own methods and materials. Judging by the repairs, Cosa was a place that represents a low level of sophistication in dolium repair technology.

4.6 *Pompeii.* At Pompeii, I examined approximately one hundred dolia; in contrast with Cosa, these consisted chiefly of materials from use-related contexts, such as *cellae vinariae*, gardens, and shop counters, that are more informative of successful repairs. Nearly a third of dolia from Pompeii were repaired with a wide range of methods, some of which were intricate and labor-intensive, while others were more simple and *ad hoc* (**Tables 4.2-4.3**).[273] Pompeian dolium repairers replicated many of the same repairs found on pottery to mend dolia, from using lead to fill cracks and sometimes even replace missing areas to forming staples (**Figs. 4.27-28**). They most often used lead to form clamps on areas where the dolium was most vulnerable and prone to cracking, and they occasionally fashioned on the

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269 Cf. Peña 2007a, 249 and 381 n. 41.

270 For an interesting study on a contemporary tinker/generalist repairer, cf. Harper 1987.

271 Cf. Lancaster 2012. I thank Lynne Lancaster for bringing this to my attention and for sharing her publications and an advanced copy of a manuscript that have been particularly relevant for this topic.

272 Some possible Latin occupational titles for builders or construction workers include *faber, abietarius* ('joiner'), or *faber intestinarius* ('joiner,' 'inlayer'); cf. Joshel 1992.

273 Cylindrical jars usually used in bar counters at Pompeii, which I argue elsewhere were not dolia but another large jar we can possibly identify with *seria*, were repaired with fills, clamps staples, and almost never with other repairs, especially the dolium specific repairs that will be presented shortly. I include them in the table to highlight the major repair differences between seemingly similar ceramic storage containers.

exterior vessel wall three crosspieces, arranged and joined in a triangular form, for more severe and irregular cracks that had begun to expand and proliferate (**Figs. 4.29-30**). Dunting (vertical cracks that formed during firing on the rim and shoulder) was also a frequent problem, and dolium repairers attempted to remedy the damage with staples or hybrid repairs that combined mortise-and-tenons or double dovetails (*MTS, MTC, DDS*), such as the ones found at Cosa (**Fig. 4.31**). These hybrid repairs both filled the voids and clamped together parts of the vessel that were separating. Chiseling and drilling into fired ceramic materials posed problems though. Not only did forming double dovetails on a fired ceramic surface during the vessel's use life often result in uneven edges, but the process could also result in additional cracks forming and spreading. There were only so many options repairers had to treat damage that appeared during a dolium's use. But if we examine the entire range of dolium repairs in Pompeii, we see differences not only between *how* repairers at Cosa and Pompeii were mending dolia, but also *when* during the vessel's life history this occurred.

Fig. 4.27. Large lead fill (and lead double dovetail) on dolium rim (II.5.5 no. 10), Pompeii.

Fig. 4.28. Thin, vertical lead fill on exterior vessel wall (I.22 no. 1), Pompeii.
Fig. 4.29. Partially preserved lead triangular clamp on dolium belly (I.21.2 n. 2), Pompeii.

Fig. 4.30. Partially preserved lead alloy triangular clamp (and hybrid clamp and mortise and tenon) repair (II.8.6 n. 1), Pompeii.

Fig. 4.31. Dolium rim, repaired with hybrid mortise and tenon staple (I.21.2 n. 2), Pompeii.

Over the course of building and manufacturing a dolium, telltale signs of manufacturing defects could emerge during the drying process, or perhaps even as early as during forming. Various dolium repairs show that dolium *makers* actually began to treat emerging damage during the *production* phase, and sometimes with materials stronger than organic elements or lead. When the dolium maker saw potential damage before or during the drying process, s/he could prepare a *production* clamp by drilling holes along both sides of the crack before firing the dolium in the kiln (**Fig. 4.32**); s/he might have also smeared some clay to 'patch' the damage (**Fig. 4.33**). Several of these *production repairs* were placed on areas where damage did not form, underscoring the artisans' attempts not only to treat but also to prevent damage. After firing the dolium in the kiln, the dolium maker or another member of the workshop formed the clamps with lead or, by combining lead with another metal, a more effective lead alloy.

Fig. 4.32. Drill hole for clamp pins, made during production (VI.14.27 frag. 1), Pompeii.

Fig. 4.33. Three double dovetails and clay smeared over horizontal crack that emerged during production phase (I.22 n. 3), Pompeii.

Fig. 4.34. Dolium repaired during production with double dovetails (I.21.2 n. 1), Pompeii.

Although dolium makers could and did use clamps occasionally to form production repairs, almost every dolium repaired during production at Pompeii was mended with double dovetails and/or a new repair technique. In order to make a double dovetails with the characteristic clean, crisp borders and consistency seen on many dolium repairs, repairers cut double dovetails when the dolium was leather-hard and already exhibited structural defects, but before it was fired (**Fig. 4.34**); we have seen double dovetails made during use, but production ones were better executed and perhaps more effective. To mend more extensive cracks, however, dolium makers employed a more elaborate technique called the *double dovetail tenon (DDT)* that featured multiple double dovetails connected by a channel or extended, linear mortise-and-tenon, a method that was employed exclusively for the repair of dolia (**Figs. 4.35-36**). In order to execute this kind of repair involved the craftsman producing a shallow (ca. 0.5-1.0 cm deep) cut into the surface of the vessel. The technique did not require drilling into the vessel walls, a process that could have further damaged the vessel if the repair were made during the use-life of the vessel (**Fig. 4.37**). Repairers applied double dovetail tenons in a horizontal orientation for fractures between coils and in a vertical orientation for dunting that commonly occurred on the rim and upper portion of the dolium. Both double dovetails and double dovetail tenons commonly exhibit densely-spaced gouges on the surface of the lead repair element, suggesting that the repairer used a chisel, spatula-like tool, or similar instrument to push and spread the lead into the cuttings, perhaps as the lead was cooling (**Fig. 4.38**). With this repair type, dolium repairs shifted from being made typically during the vessel's use to its production, and the task of repairing dolia fell increasingly in the realm of the dolium production. This repair's effectiveness was noted, and some repairers occasionally adapted it as hybrid repairs for damage that occurred during use-life (**Figs. 4.39-41**).

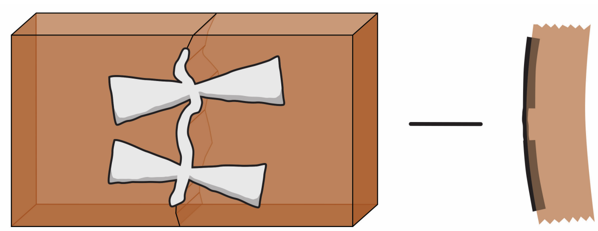


Fig. 4.35. Illustration of double dovetail tenon repair technique, by Gina Tibbott.

Fig. 4.36. Dolium repaired with double dovetail tenons during production (I.22 n. 3), Pompeii.

Fig. 4.37. Lead alloy double dovetail tenon, shallow cuttings visible (I.22 n. 3), Pompeii.

Fig. 4.38. Gouges on surface of lead (alloy?) double dovetail tenon (I.22 n. 3), Pompeii.

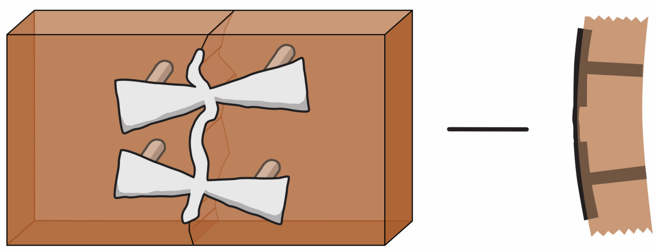


Fig. 4.39. Illustration of hybrid double dovetail tenon and staple technique, by Gina Tibbott.

Fig. 4.40. (L) Exterior view of damaged area repaired by stapled double dovetail tenon made during use (I.22. n. 7). Pompeii

Fig. 4.41. (R) Interior view of vessel showing lead fill for crack and drill holes for stapled double dovetail tenon made during use (I.22 n. 7), Pompeii.

Overall, dolia from Pompeii were repaired with staples, clamps, double dovetails, and double dovetail tenons, and occasionally with fills or hybrid combinations of different methods (**Figs. 4.42-43**). Pompeian craftsmen formed dolium repairs during both the production-phase and the use-life of the vessels. Dolium makers or other members of the workshop made important developments as they employed preventative measures, preparing lead alloys to form double dovetails or double dovetail tenons, to repair defect that had appeared in production or damage that could form later. Yet substantial damage could still occur during the use of the vessel. Depending on the severity of the damage, various workers, such as pottery menders, tinkers, architectural workers, and craftsmen who worked with lead (*plumbarii* or *artifices plumbarii*), repaired the vessel using materials and techniques that they knew, from lead fills to staples and clamps to hybrid repairs.[274] These were the same techniques, and probably the same general workforces, that repaired other large terracotta objects and vessels in Pompeii.[275] Excavations at Herculaneum have also uncovered a workshop that likely manufactured lead repairs as well as lead and lead alloy (possibly lead and tin) objects, testifying to the importance of lead for repairing things in antiquity;[276] Pompeii might have had a similar workshop, where some of the repairers might have obtained materials, performed certain tasks, or were employed.

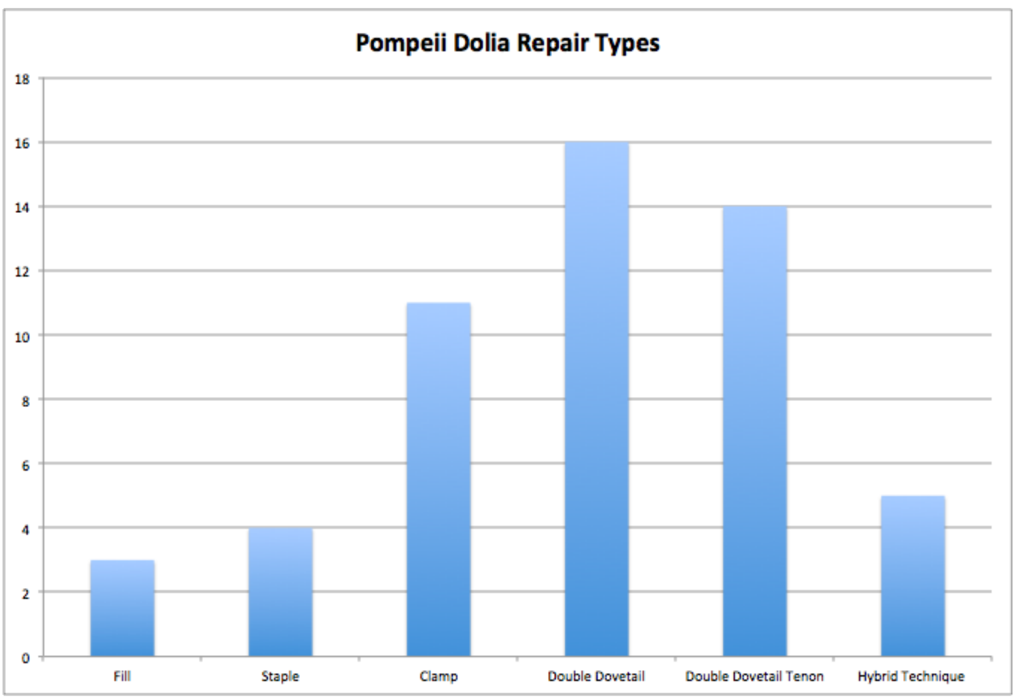


Fig. 4.42. Various dolium repair types found on dolia at Pompeii.

[274] Joshel 1992: A *plumbarius* was 'a maker of lead pipes' or a 'plumber' and *artifices plumbarii* were 'workers in lead, plumbers. Although there were other occupations associated with specific metals – goldsmiths (*aurifex, aurarius*), silversmith (*argentarius, faber argentarius*), ironsmiths (*ferrarius, faber ferrarius*), and workers of Corinthian bronze (*corinthiarius*) – lead workers were probably associated with pipes and plumbing, perhaps because the working of lead itself was not considered a specialized craft.

[275] These workforces probably also repaired the cylindrical jars usually used in bar counters at Pompeii.

[276] Cf. Brun et al 2005, 329-337: various lead and lead-tin (?) objects and a crucible were found.

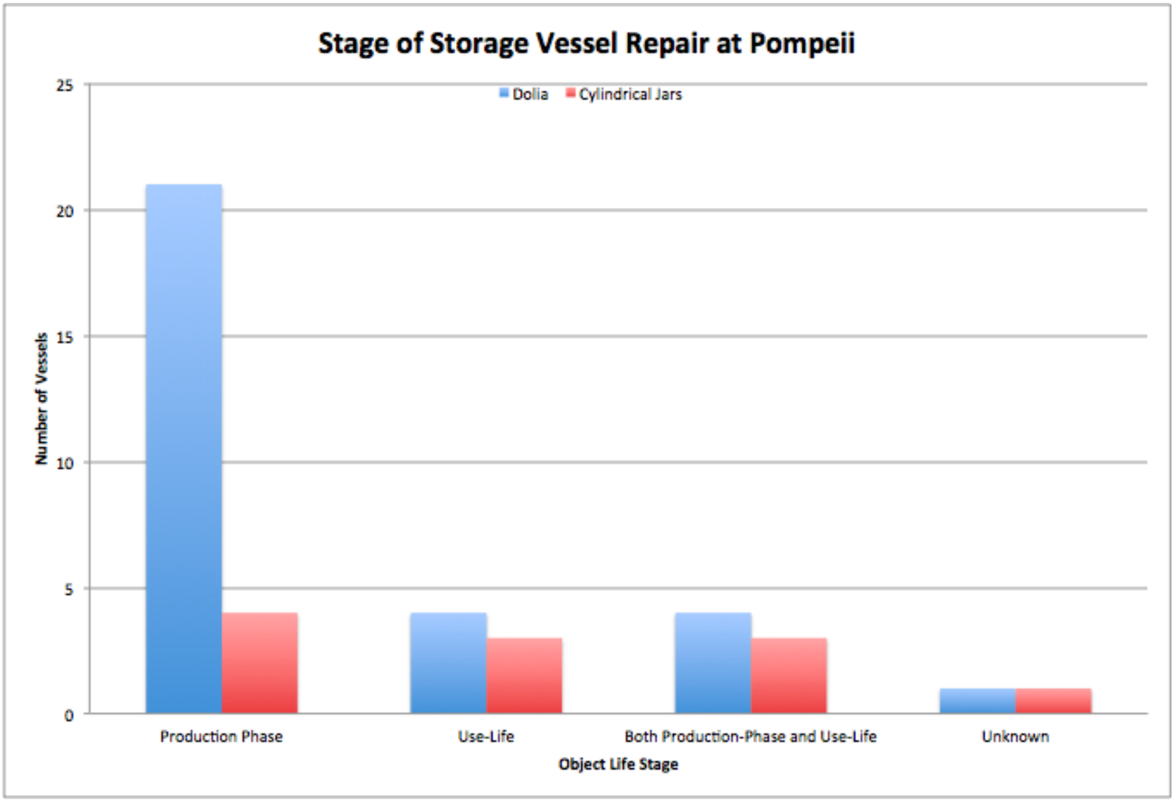


Fig. 4.43. Repairs on different storage vessels in Pompeii, according to vessel type and stage.

4.7 ***Ostia.*** For any discussion on dolia and dolium repairs, Ostia represents the pinnacle of the development of dolium repairs. Perhaps the most important port for Rome and the center of Roman food storage, Ostia had almost two hundred buried dolia, of which about a hundred are still visible today. I was able to examine one hundred dolia, which all were buried as *dolia defossa* in one of three horrea outfitted for the storage of liquids; unlike the dolia at Cosa and Pompeii, then, the Ostian dolia were installed and used for a specific application: storing wine and/or oil. Since the dolia were buried, and many were also broken, there is not a single complete dolium that can be seen in its entirety, yet despite this limited visibility, it is clear that at least nearly half the dolia (**40%**) were repaired.[277] Although so many of the dolia at Ostia were repaired, there are only three types of repairs: (1) fills, (2) double dovetails, and (3) double dovetail tenons (**Fig. 4.44**, **Tables 4.4-4.5**). These three types of repair, each of which was very consistent, suggest that the repairs on the dolia at Ostia were made by a small group of experts who might have been responsible for maintaining the vessels.

[277] The only view that is lacking is the base. Approximately 40% dolia were repaired, though the limited views and fragmentary nature must obfuscate a much higher number.

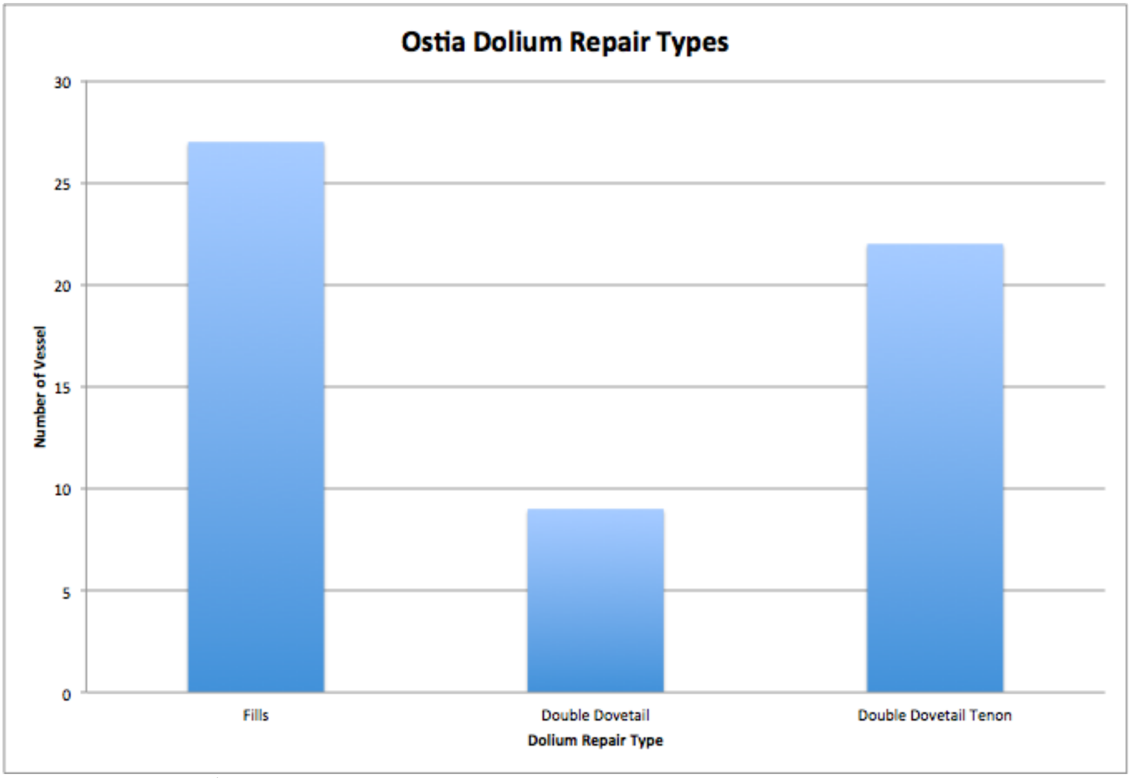


Fig. 4.44. Various dolium repair types at Ostia.

At Ostia, we can see that dolium makers took many preemptive measures to anticipate and treat potential damage early on. More than half of Ostian dolium repairs used double dovetails (**19%**) or double dovetail tenons (**44%**) that were made during the production process. Repairers placed double dovetail tenons where there were more extensive cracks emerging on the vessel, often carefully and strategically shaping the repairs and filling them with stronger lead alloys (**Fig. 4.45**). Unlike the production repairs found at Pompeii, many of the double dovetails and double dovetail tenons at Ostia appeared on the rim's upper surface to mediate dunting cracks that might form during the firing process; since these double dovetails were placed on an area where cracks were expected to form during firing, but would *not* appear during the vessel's bone-dry phase when the repair was made, they provide evidence for the dolium maker's effort and ability to *anticipate* damage (**Fig. 4.46**).

Fig. 4.45. (L) Dolium with lead double dovetail tenon around shoulder (I.4.5 n. 28), Ostia.
Fig. 4.46. (R) Dunting on rim and shoulder repaired during production (I.4.5 n. 17), Ostia.

The great skill these dolium makers had developed to form production repairs is further attested by another example: one dolium featured a double dovetail tenon on the *interior* wall as well (**Fig. 4.47**), which suggests that dolium makers were able to climb into the dolium and mend the interior surface before the vessel was fired in the kiln.[278] This was a challenging and very unusual feat. To do this, one needs both an extremely high quality and well-prepared ceramic material for the vessel and for the potter to know exactly when the unfired vessel would be strong enough to support a person's weight. If it was indeed made during the production-process, this suggests that members of the *opus doliare* workshops (or their children) commonly inspected the interiors of dolia before firing. This double dovetail tenon seems to have been made during the production-phase, but it is possible that it was made during use-life. If it had been made during the vessel's *use,* then it demonstrates how the repairer tried to apply the workshop's technique to use-life damage. Because these tasks required entering tight spaces, and child labor was fairly common in antiquity, it is possible that some of these jobs were done by children.[279] After the vessel was fired, the artisans applied lead or a lead alloy into the double dovetail and double dovetail tenon mortises. For more vulnerable areas, artisans often utilized more of the stronger metal in the lead alloy to

[278] Because these tasks required entering tight spaces, and child labor was fairly common in antiquity, children could have done some of these jobs; I thank Ted Peña and Lynne Lancaster for this suggestion.
[279] Groggy clay, such as clay used for dolia, could have incredibly high levels of 'green strength' (the strength of a clay body in dried form, which aids in handling during production). It is possible that the clay body used for dolia could support the weight of a person when it dried between a leather-hard and a bone-dry state. I thank Gina Tibbott, an experienced potter, for alerting me to this astounding property of clay.

reinforce the repairs. These repairs were effective and prevented possible damage down the road and were probably preferable to the more invasive use repairs, especially if these use repairs were done with staples and clamps.

Fig. 4.47. Lead double dovetail tenon on interior lower wall of dolium (V.6.5 n. 52), Ostia.

Lead and lead alloy fills appear on almost every other repaired vessel (**47%**), and repaired minor cracks that formed on the surface, even on the interior wall of the vessel (**Figs. 4.48-49**).[280] They could, in principle, have been production or use repairs. The material of the fill can help us decide this (**Fig. 4.50**). Lead was a metal that was relatively easy to manipulate and use and, due to its low melting point, could have been used anywhere; an open flame would have been enough to bring the metal to a liquid and malleable state. Lead alloys, on the other hand, required some metallurgical expertise and special equipment, suggesting that lead alloys were prepared and employed in the workshop, but not used in the field for use repairs.[281] This is confirmed in Pompeii, where no lead alloy has been positively associated with a use repair. Since all double dovetails and double dovetail tenons were made during production, half of the dolium repairs at Ostia are securely identified as having been made during the production of the vessel. If all lead alloy fills are production repairs (in addition to

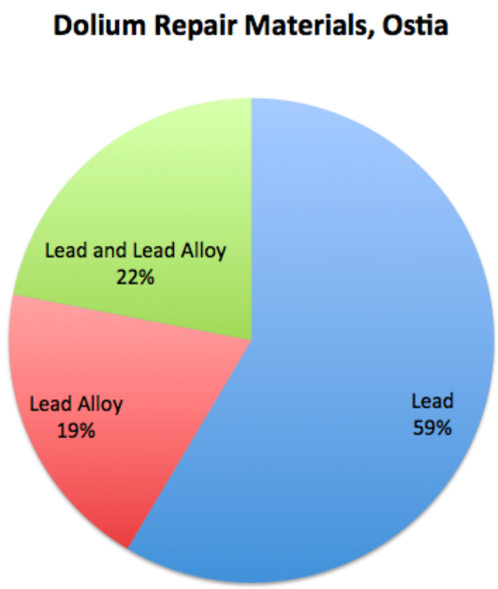
[280] Fills on interior walls have not been observed at other sites. Doing this meant that repairers would often climb into a dolium to identify and seal cracks that had formed.

[281] As mentioned previously, the lead workshop in Herculaneum also produced lead alloy objects. Precautions were taken to protect the workshop from the combustion zone, where the lead and lead alloy were heated in a crucible at a fixed workspace.

double dovetails and double dovetail tenons), then an astonishing 80% of dolium repairs at Ostia were production repairs (**Fig. 4.51**).[282] If this is the case, it is truly extraordinary and means that repairers, who were most likely the dolium makers themselves or at least a member of the workshop, preemptively repaired a third of the dolia they made using sophisticated and strong lead alloys for double dovetails, double dovetail tenons, and fills during the production phase. This level of intense investment at such an early stage is unparalleled. At the same time, there were no staples or clamps. None of the Ostian dolium repairs involved any drilling that would have made the vessels more vulnerable and susceptible to further damage or breakage. Based on the quality and consistency of the dolium repairs at Ostia, specialized dolium makers in the large *opus doliare* workshops, who had knowledge of metallurgy and architectural clamping techniques, or outsider specialist craftsmen commissioned by the workshop repaired dolia with double dovetails, double dovetail tenons, and fills during *production,* while repairers that serviced Ostia only used fills to mend dolia during their *use*.


Fig. 4.48. (L) Lead fill on interior vessel wall (V.6.5 n. 61), Ostia.
Fig. 4.49. (R) Lead alloy fills on interior vessel wall (V.6.5 n. 8), Ostia.

282 Some dolia at Ostia were repaired with both lead and lead alloy materials. Repairers might have chosen to form a double dovetail tenon with lead alloy for emerging damage that seemed especially dangerous, while forming a double dovetail with lead for a minor crack. But the same explanation probably does not apply to fills made with both materials on the same dolium. The more likely explanation for that scenario is that the dolium maker or another member of the workshop filled a crack during the production-phase with lead alloy, but the dolium cracked again during its use-life, prompting another craftsman, perhaps a specialist repairperson, to apply lead (the metal used in the field) to the crack.



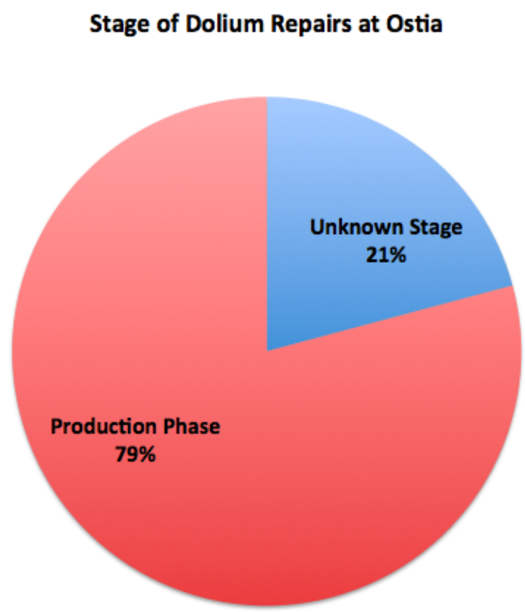


Fig. 4.50. (L) Pie chart showing proportion of metals used for dolium repairs at Ostia.
Fig. 4.51. (R) Pie chart of proportion of Ostian dolium repairs made during production vs. use, with lead alloy fills considered production repairs.

By the second century CE, craftsmen repairing dolia for Ostia used well-established techniques: dolium workshops in the Tiber Valley had a protocol with repair methods and materials for damage emerging during a dolium's production, while repairers at Ostia only repaired dolia during their use with lead fills. What is most notable about the repairs on the Ostian dolia is how many were made during the production phase (80% of repaired dolia, 32% of all dolia). The large number of double dovetails and double dovetail tenons, and the absence of clamps and staples could mean two things. When a dolium cracked or broke while in use, it was simply discarded. Repairing serious cracks that formed after a dolium had already been fired with staples or clamps was a risky endeavor that could easily lead to the vessel breaking entirely. Rather than find (and pay) a repairer to drill through the vessel in order to make staples or clamps that might have broken the vessel, resources could instead have been directed to replacing the dolium entirely. Furthermore, the low number of dolium fragments found at Ostia suggest that the rate of breakage was low and that the dolia at Ostia were more robust and less likely to crack during use, probably because dolium makers manufacturing these large storage vessels became better at not only making dolia, but also both anticipating and preventing potential cracks and damage. The manufacturing defects that necessitated the repair of these vessels during the production phase probably stemmed from the fact that these vessels were exceptionally large, with unusually thick walls that were highly susceptible to crack formation during drying and firing. In order to construct, and then be able to sell, such large storage vessels for Ostia, then, manufacturers also had to develop the technology for forming effective interventions on dolia during the critical stage when the repair could be successful without risking further damage to the vessel.

4.8 ***An Overview of Dolium Repairs and Repairers.*** Due to the high value of dolia, different repairers used various metals and a range of techniques to mend these large ceramic storage containers, and it would be useful to survey the different dolium repair techniques that we have seen at Cosa, Pompeii, and Ostia (**Tables 4.6-4.7**): lead (alloy) fills; staples; clamps; hybrid techniques combining the mortise and tenon; double dovetails; and double dovetail tenons. The survey of dolium repairs at Cosa, Pompeii, and Ostia also shows a range of skills and tools that, combined with when the repair was made, help us envisage possible identities of dolium repairers.

Lead by itself or paired with another metal as an alloy could be applied to a crack as a filler material (**Fig. 4.7**). Because of lead's low melting point, filling a crack with lead was done after the vessel was fired in the kiln, and would be done either in the final step in the production phase of the dolium or while the vessel was in use.[283] Lead fills were convenient since they could be applied to cracks that developed at any point in the vessel's life, and could be used for small cracks that had formed; even non-specialists could use lead. It is difficult to establish the possible identity of whoever made fill repairs since it did not require specialist expertise. A member of the dolium workshop could have added lead or lead alloy to cracks that had formed during drying or the firing process at the end of the production phase; for cracks that formed during the vessel's use-life, a tinker, specialist repairer, or even the dolium user could have filled the cracks with lead (**Fig. 4.52**). Lead alloys, however, were likely prepared by specialists, and depending on the other metal(s), may have required access to a furnace and were likely made during the production phase of the dolium's life history.[284] Overall, fills would prevent a dolium's product from seeping into the vessel, which could turn rancid and adulterate the future batches of contents, and could also prevent further minor damage from occurring, but they did not offer sufficient support for more substantial damage.

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[283] Cato *de Agri Cultura* 39 includes the mending with lead or binding with organic fibers of dolia as a task that farmhands could perform when bad weather prevented them from working in the fields.

[284] As mentioned in this section, tin had a melting point of 232 C and copper had a melting point of 1085 C. Working copper required a furnace, and forming a stable alloy required some metallurgic knowledge.

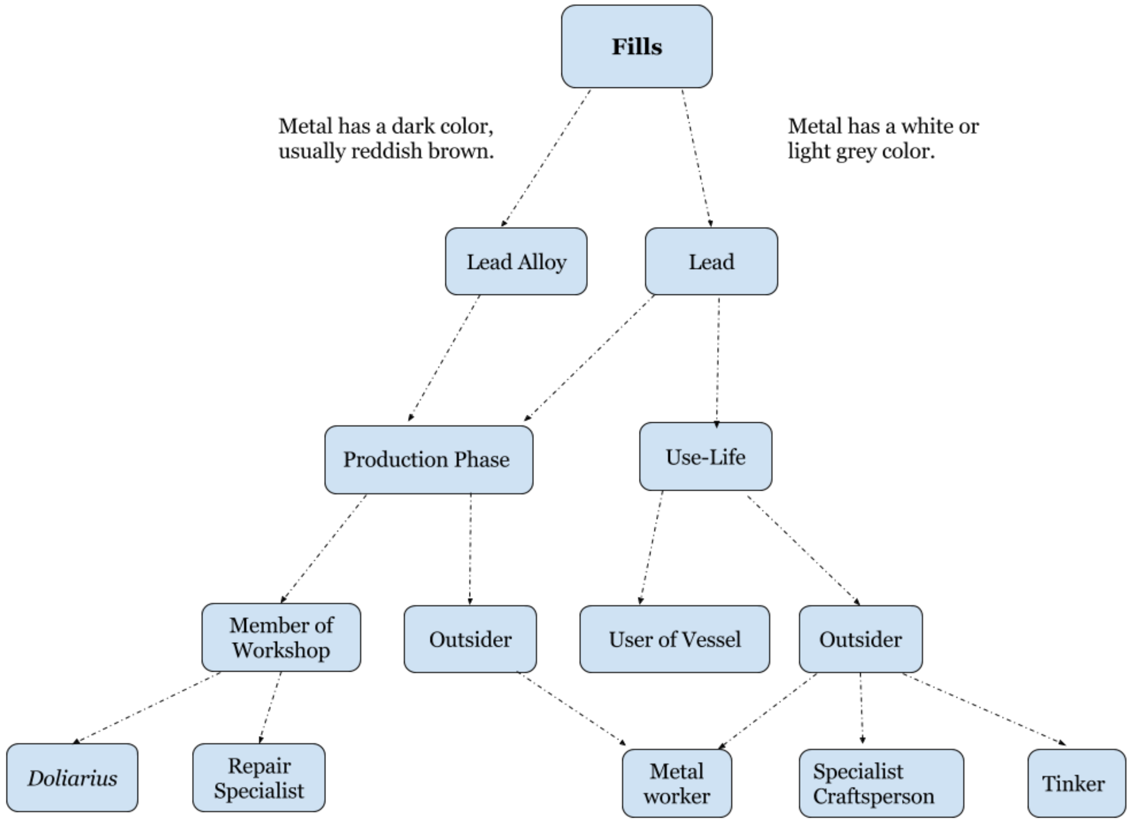

Fig. 4.52. Possible producers of lead (alloy) fills on dolia.

More severely damaged dolia were occasionally repaired with the traditional pottery mending techniques of staples and clamps for more structural support.[285] Artisans formed ***staples*** (**Fig. 4.8**) and ***clamps*** (**Fig. 4.9**) by using a bow drill to drill through the vessel wall on either side of the crack in order to bridge the two halves and garner more tensile strength; forming these repairs could occur during the production phase or the use-life of the dolium, but seems to have been made predominantly during the use-life.[286] Staples required drilling into, and occasionally through, the vessel wall to place the staple pins or legs and a crosspiece would join the two pins, usually on the exterior vessel wall. Some of the staple repairs were made with small pins that did not go completely through the vessel walls, which might have been an attempt to control the drilling action and limit its potential damage to the vessel.[287] A clamp was like a double-sided staple; to form it involved drilling through the vessel wall to anchor the two pins, which were joined by crosspieces, likely made in molds, on both the

285 Rotroff 2011: lead clamps were the most prevalent type of pottery repair found on pottery from the Athenian Agora. This type of repair appeared early on, such as on pithoi from the Middle Helladic period.
286 As mentioned in the previous section, architects and civil engineers use the term 'cramps' for metal bars with bent edges for holding together building stones. Ceramicists use the term 'staples' to describe the same type of joining technique found on ceramics. This study will employ the term 'staple.'
287 These repairs were also found on Greek pottery, cf. Dooijes and Nieuwenhuyse 2007, 16-17.

interior and exterior vessel walls.[288] These were common use-life repairs that pottery menders and tinkers likely formed, using lead, when the vessel was damaged in use (**Fig. 4.53**).

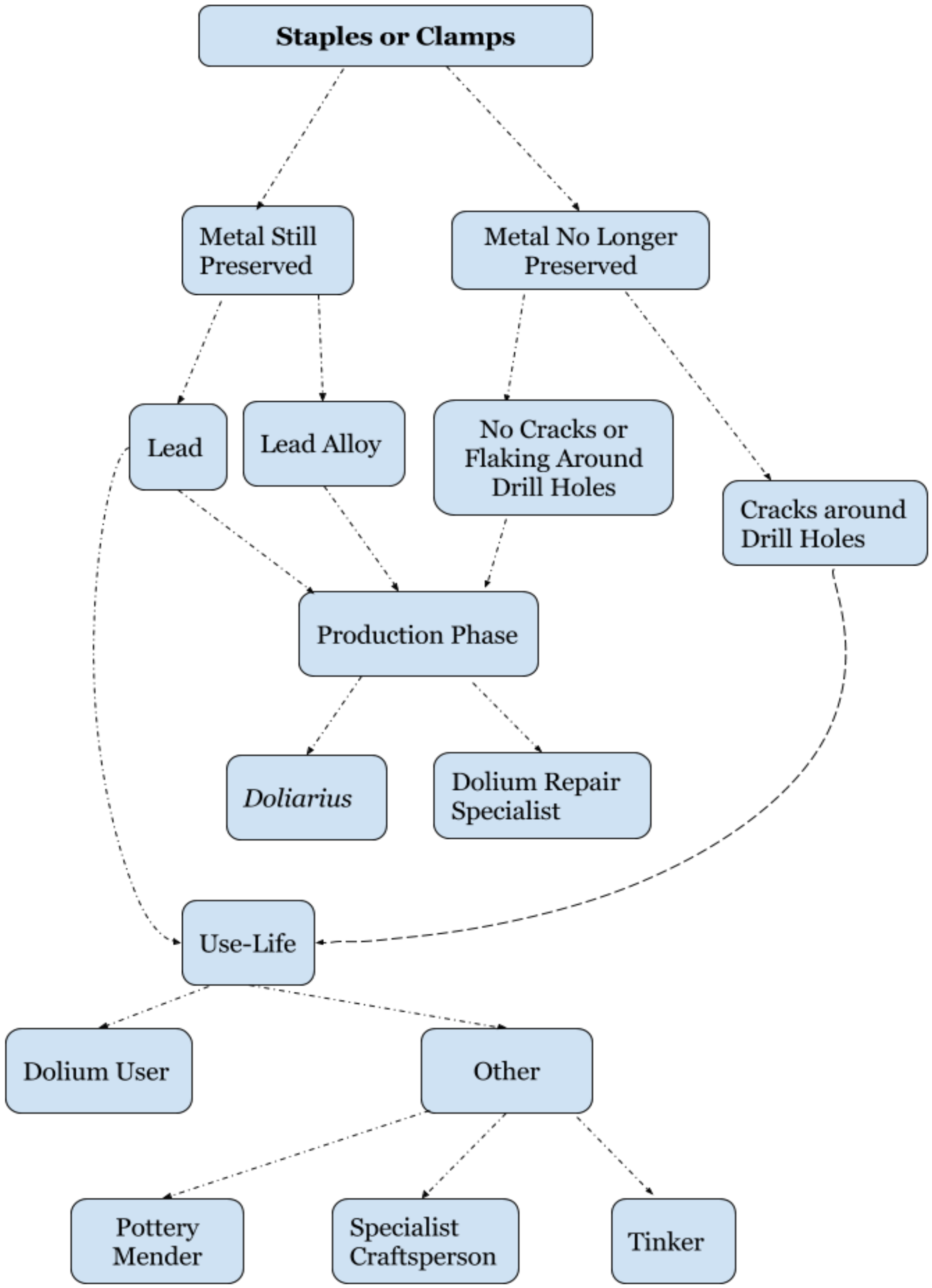

Fig. 4.53. Possible producers of staples and clamps on dolia.

[288] Peña 2007a, 239.

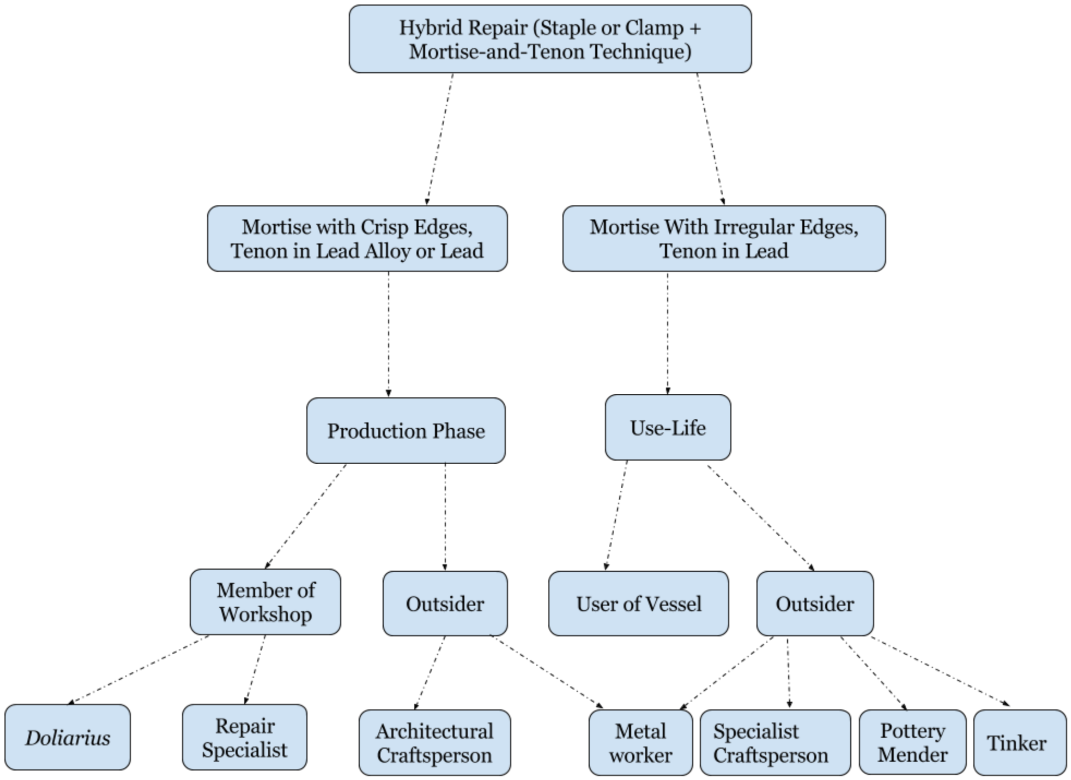

Fig. 4.54. Possible producers of hybrid repairs on dolia.

In order to strengthen and improve dolium repairs, craftspeople began to utilize methods not commonly found on pottery that required cutting or chiseling into the dolium's surface to regularize cracks. Artisans, probably tinkers or craftsmen with experience in architecture, modified the staple or clamp repair by combining it with the architectural joinery technique known as the mortise-and-tenon (**Fig. 4.16, 4.54**). This hybrid repair technique, usually done during the vessel's use-life, involved carving a slot, often rectangular, into the vessel wall, drilling two pin holes near each end, and setting metal into the slot, which kept the staple or clamp in place. Some hybrid repair techniques were not rectangular, but used the double dovetail shape (**Fig. 4.17**). Based on the hybrid repairs found at Cosa and Pompeii, hybrid repairs were use-life repairs that were probably the results of attempts to improve the staple and clamp techniques.

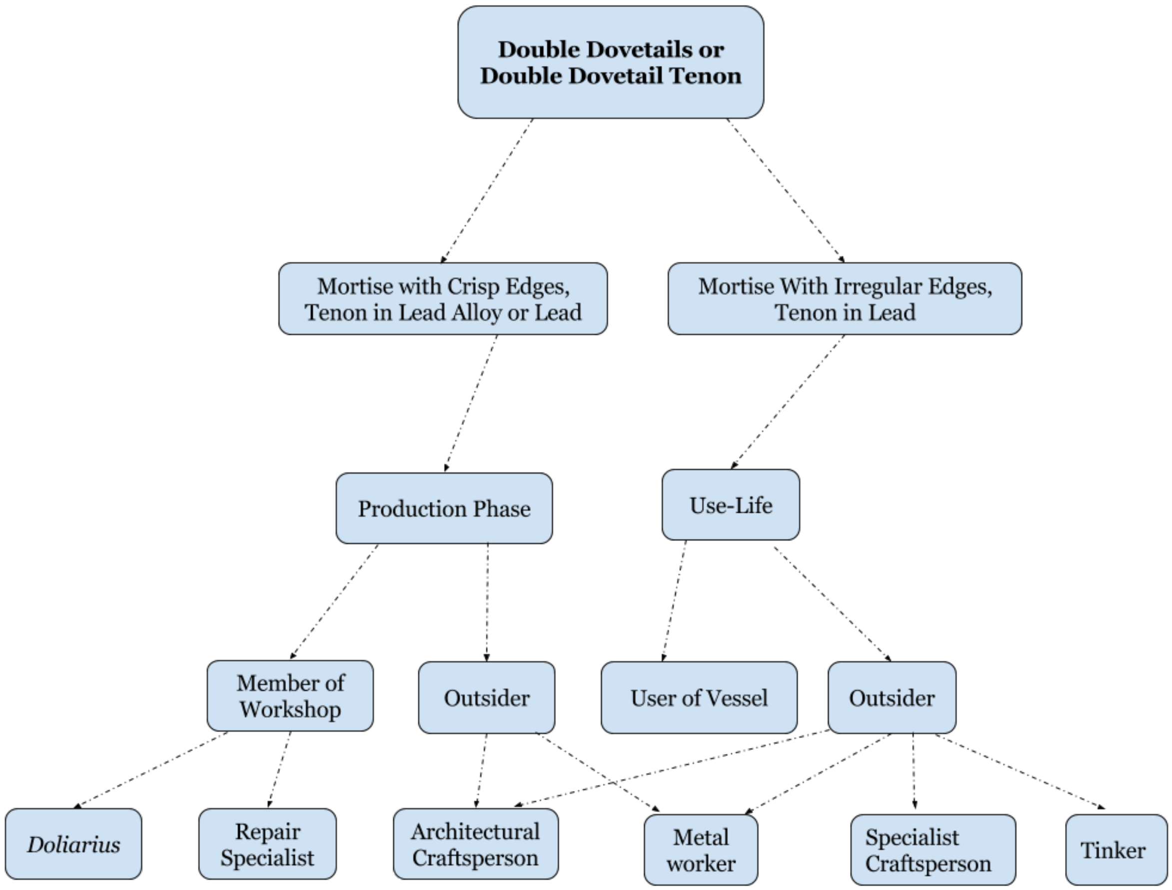

Fig. 4.55. Possible producers of double dovetails and double dovetail tenons on dolia.

Some dolium repairers developed, from the architectural realm, a different, less invasive technique known as the double dovetail, which also helped anchor the repair more securely and provided some tensile strength. Carving a mortise on a fired ceramic surface resulted in ragged and uneven edges, so post-production double dovetail joins contrast greatly with production-phase ones. This is even more apparent with repairs that feature multiple double dovetails connected by a channel or extended, linear mortise-and-tenon, a technique called a ***double dovetail tenon*** **(DDT)**. In order to make a mortise with the characteristic clean, crisp borders and consistency seen on almost every double dovetail and double dovetail tenon, members of the dolium workshop must have identified or anticipated cracks when the vessel had dried and cut double dovetails and double dovetail tenons into the vessel's surface before the vessel was fired in the kiln. After firing, the cuttings were filled with lead or lead alloy, using tool such as a small spatula or putty knife to apply and push the metal into the cut slots. Since these dolium repairs were executed during the production phase, they were probably made by a member of the workshop, such as the dolium maker or a designated dolium mender, or by an outside specialist craftsman commissioned from a neighboring workshop, such as someone from the architectural industry or a metallurgist (**Fig. 4.55**).[289]

4.9 *The development of dolium repairs in west-central Italy.* The chronology and geographic distribution of the different dolium repair methods at Cosa, Pompeii, and Ostia suggests that, in certain environments, and perhaps over time, dolium makers, repairers, and users better understood the vessels' material and morphological properties (**Table 8**). This development of their knowledge and skills can, in rough outline, be described by following the improvements of their methods. Let us therefore consider the obvious disadvantages of some repair methods as well as the easily observed relative advantages of other methods. Some of the earliest dated ceramic storage containers (both *pithoi* and dolia, as well as other large storage jars) feature the traditional pottery mending method: clamps. Clamps could be applied during the vessels' production, but that was rare. They were more commonly applied during the vessel's use, when the drilling process actually made the vessel vulnerable to further damage. A clamp could be accidentally damaged or detached since its crosspieces were on top of the vessel's surface. Furthermore, forming a successful clamp would probably result in a leaky vessel that was also difficult to clean and maintain and could taint the contents.[290] For these reasons, drilling only partway through the vessel wall to form staples could have been a better alternative. With a crosspiece only on the outer wall of the vessel, many of the problems with clamps could be avoided. These concerns probably motivated the formation of hybrid repairs that combined clamps or staples with the mortise-and-tenon technique. The hybrid technique meant that the crosspiece was often flush against the vessel wall since it was inserted into the slot carved or chiseled into the vessel wall, diminishing the likelihood of damaging the repair. But it was the less invasive double dovetail-shaped mortise-and-tenon method that had the qualities dolium repairers (and users) desired. By cutting and filling a shallow double dovetail, repairers made a repair that was both a fill and an anchor, no drilling required.[291] By gradually improving their grasp of the materials – both ceramic and metal – dolium repairers found ways to work and combine them in successful and effective ways.

These new, innovative dolium repairs, however, were not developed by the craftspeople traditionally tasked with *repairing* dolia, i.e. the pottery menders, tinkers, among others. Instead, they were developed and refined by those *making* the vessels in the workshops. This might seem unexpected, or even odd, but not if we consider the context and

[289] Forming production-phase double dovetails and double dovetail tenons also could have featured two separate workforces, ex. the *doliarius* or some other member of the workshop cut mortises and a metallurgist added the metal tenons.

[290] Any area where the lead or lead alloy did not fill the drill hole completely could lead to leaks. This would have been mitigated to some extent by the pitch lining the walls of the vessel, but the clamp would have also posed problems in the lining, cleaning and relining process. Lead clamps would have melted if workers used a torch to remove residual pitch in the cleaning process as described by Columella 12.18.5-7.

[291] Since the metal elements of some double dovetails and double dovetail tenons are still preserved, it is impossible to know whether those were hybrid repairs (with staple pins) or not. A few dolium repairs (Pompeii II.6.8 n. 1, Pompeii Villa of the Mysteries n. 3, Pompeii Dolium Lid n. 1; and aforementioned examples at Cosa) do show a combination of these dolium repair types.

environment where these repairs developed. Pottery menders and tinkers probably worked alone, each one likely covering an area of the countryside or a neighborhood in a town or city. Dolium makers, on the other hand, worked together in workshops where they shared resources and knowledge. Moreover, dolium workshops, especially *opus doliare* workshops, were situated near good clay sources and might have been in the vicinity of other major workshops, not only for the sharing and exchange of space, materials, and equipment, but also for social and economic reasons.[292] Workshop location alone might have been how the right kinds of people got together. The proximity and potential interactions at least could have inspired dolium makers to experiment with different methods and alloys and exposed them to new tools; the tools for staples and clamps (molds for crosspieces and a bow drill to drill pin holes) differed from those used for mortise-and-tenon clamps (instruments resembling spatulas and scalpels). Furthermore, the production of dolia in brick and tile workshops were important conditions for bridging the gap between the domains of large-scale pottery production and construction.

As dolium makers achieved a more sophisticated understanding of the properties of the materials they were working with, they were able to develop techniques for the remediation of defects that occurred in the course of the production process.[293] In addition, the convergence of dolium production with the manufacture of bricks and tiles, which gained traction starting in the second century BCE, was a factor in the widespread adoption of the double dovetail clamping method. Members of the workshop might have noticed double dovetails used in building projects to join ashlar masonry or seen how marble statues were joined and how stone funerary urns and sarcophagi were sealed.[294] Dolium makers could have seen and adapted the technique of double dovetail joins that were used in manufacturing wooden brick and tile molds.[295] There were many opportunities to see how these methods were used in other industries.

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292 Goodman 2016: in both pre-modern and contemporary societies, workshops are usually clustered in urban areas due to the social networks and professional associations and their status among elite landowners. Miller 2009 persuasively argues that cross-craft interactions, which could have been brought on by shared tools, techniques, and organizational methods, can illuminate social dynamics and organization of labor in ancient technology and craft production.

293 Although the mental and practical processes of craftsmanship and experimentation are not central to this chapter, some of the ideas developed by sociologists, anthropologists, and craftsmen themselves are helpful for understanding not only how craftsmen begin to make innovations, but also the conditions of the workplace and industry that help drive them (cf. Sennett 2008; Ingold 2013; Korn 2013; Harper 1987; Csikszentmihalyi 1996). Creative work required an established a field (specialized area of knowledge) and a domain (a set of individuals who determine what belongs in the field) in addition to a creative individual.

294 For discussion on joining techniques for statuary, cf. Claridge 1990; Wootton et al. 2013.

295 Very few brick and tile molds are preserved. Those that are known and published were found in pharaonic Egypt and were joined with mortise-and-tenon joints; examples include a wooden brick mold from Kahun at the Manchester Museum, acc. no. 51 and wooden brick molds from Hatshepsut's temple at the Metropolitan Museum of Art acc. nos. 22.3.252 (15th BCE), 30.8.7 (15th c. BCE), 25.3.108 (16th-13th c. BCE). Ulrich 2007, 66: archaeological finds show that Roman carpenters used dovetail joints to connect the sides of boxes.

But there also had to be a serious catalyst that spurred the curiosity and attempt to test these different methods on dolia, especially during the production process. Since these were production repairs, their use and success meant that not only did dolium makers decide they needed or wanted to make repairs, a task that was generally done when the vessel was in use and by outside craftspeople, but also they had to devise methods to form anchors on *pre-fired* vessels, a feat that traditional potters did not typically do. This was risky. If they made a mistake forming the repair, something would go wrong when they fired the dolium. Cutting too deeply into the vessel wall to form double dovetail tenons could undercut the structural stability of the vessel; the dolium could collapse during firing. Not cutting enough could do nothing or, worse, deepen the nascent crack. The workshop therefore had to be a craft environment with an openness and proclivity for experimentation, especially with techniques used in a different industry. The traditional craftsmen mending pottery, on the other hand, might not have had the opportunities to learn or even attempt new or different repair methods; because dolium owners and users hired dolium repairers directly, repairers might have been restricted in what techniques they could employ. The *padrone* of Pirandello's *La Giara*, for example, insisted the *conciabrocche* ("curer of jugs") use the traditional stapling technique, not a new gluing technique the *conciabrocche* had developed, to repair his *giara*.[296] Dolium owners hiring, and paying, a craftsman could wield considerable influence over what techniques the repairer employed, and they probably favored conservative methods that were known to work to some extent.

Both the nature of the organization of dolium workshops and the advantages that were to be gained from developing a reputation for the manufacture of superior, long-lasting productions, induced dolium makers to work collaboratively with a view to developing methods that would allow them to manufacture increasingly larger, more durable vessels. As **Chapter 3** discussed, dolium workshops, especially the larger *opus doliare* ones that produced multiple products, could have had many workers with different roles and expertise; some of these workers worked seasonally and might have had jobs in other industries, such as agriculture or construction, where they saw different joining or clamping techniques or even interacted with dolium users or repairers who reported their impressions (and complaints) of the vessels and repair techniques.[297] Large *opus doliare* workshops that remained in operation year round, were perhaps better positioned to perfect these methods because of their more extensive set of manufacturing tools and facilities, more varied body of expertise, and relatively large output. We can imagine, for example, that the workers of these large manufacturies practiced and mastered the repair techniques of double dovetail tenons on bricks and tiles before adopting these methods for the substantially more challenging task of repairing dolia. There was a certain level of cooperation and cohesion in the workshop since members had to work together in different capacities to acquire and prepare raw materials; gradually form and coil-build the vessel and turn the wheel; form production repairs, which

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[296] The *padrone* said, "Col mastice solo però non mi fido. Ci voglio anche i punti" (But I don't trust just the glue. I want also the staples).

[297] Kang 2015: a traditional Korean *onggi* potter faced many challenges when trying to revive the craft of *jeolla* style *onggi* pots (they have a prominent bulge at the belly); because these *onggi* pots were particularly difficult to make, they were also expensive, and customers demanded replacements if there was damage because they paid so much.

included identifying damage, regularizing cracks, and forming the metal tenons; move the vessels; load and unload the kiln; and fire the kiln. We can conjecture that the creative interaction between the workers in dolium workshops, between the dolium workshops, and between the dolium workshops and workers engaged in other kinds of craft production rendered the dolium industry a vibrant and creative one that was capable of adopting and adapting innovative production and repair techniques that were probably vital to manufactories producing and trying to sell large quantities of dolia.[298]

4.10 ***Conclusion***. The operation and organization for fixing dolia was vital not only for the vessels, but also for the general success of the dolium production industries. Unlike other containers such as skin containers, which occasionally required upkeep or repairs by craftsmen who were likely also makers, once they were out of the workshop, dolia were no longer attached to or dependent on dolium makers to function. Use repairs were separate, independent activities that fell under the aegis of other crafts and expertise: pottery mending, construction, metallurgy, and even non-specialist handiwork. Use repairs were more makeshift and were often of uneven and sometimes inferior quality. By repairing production flaws well, then, dolia were not as likely to suffer any more than minor cracking during use, as we have seen in Ostia. The workshop's tremendous input at the outset to treat, detect, and anticipate damage during production made dolia more robust and cultivated an expectation for quality that freed the dolium users and owners from complicated repairs down the line.

To support a growing wine industry, then, dolium makers took on the enormous task of creating a bigger and better dolium. But its construction was so complex and time-consuming, that, in the end, the vessel was very expensive, yet cracked easily. For at least half the history of the dolium industry, the cracks that so frequently appeared on dolia were fixed with materials and methods that were not suitable or effective. It was only well into the second half of the industry's history that that the development of dolium repairs reached its pinnacle, with repairs that eliminated future damage and even made the final product much more robust. But it took a long time to get to this point, and the development was not even.

Although an overview of dolium repairs found at Cosa, Pompeii, and Ostia suggests a chronological development, there were other possible factors at play. Given the absence of evidence for the techniques employed for the repair of dolia at Cosa after the early first century CE and at Pompeii after its destruction in 79 CE, we do not know whether craftsmen working in these towns would have eventually adopted repair techniques similar to those attested at Ostia in the second century CE. And the technology of dolium repairs (and production) did not necessarily follow a teleological evolution. It is probably best to assume that stability and change in repair techniques in place was to some extent driven by local considerations, including the number and density of workshops and the attitudes of and interactions between the specific craftsmen involved. At Ostia, we see the products of such a workshop environment. Dolium makers reinforced many dolia there with lead and lead alloy interventions in the workshop; the few dolia that were damaged while in use required only minor touch ups. At the producer sites of Pompeii and Cosa, however, these workshops never

[298] Cf. Murphy 2017 for discussion on learning in pottery workshops and through generations of potters at Sagalassos.

reached the same level of skill as the *opus doliare* workshops supplying Ostia. Some of the production repairs at Pompeii were effective and well-made, but they lacked the strength, consistency, and *anticipatory* nature of the Ostian repairs.[299] The robustness and high-quality of dolia and dolium repairs at Ostia should therefore not be viewed as the pinnacle of dolium repair technology at *all* workshops, but workshops equipped with the expert skill and knowledge in an environment where innovation was fostered. This was probably also crucial for the ability of the workshop both to manufacture and to sell a large quantity of dolia, especially when dolium makers at *opus doliare* workshops were making bigger vessels.

But environment mattered just as much for production-phase repairs as for use-repairs. At both Pompeii and Cosa, many dolia became damaged during use and were repaired by various non-specialists who applied an assortment of techniques. At Ostia, on the other hand, dolia damaged while in use were patched with lead-fills made in a consistent way. The wide range of repair techniques at Pompeii and Cosa was likely related to their dispersed loci of use in the towns. Owners of dolia at shops, gardens, vineyards, and houses found different craftspeople to mend dolia, whereas the few storehouses in which the Ostian dolia were found were probably regularly maintained by a dedicated staff that followed certain protocols. Different loci of use, as **Chapter 5** will discuss, not only resulted in different ways dolia were used and repaired, but also diverse modes of maintenance and organizing labor.

[299] Only a handful of Pompeian production repairs targeted areas where dunting could form during the firing process, whereas Ostian production repairs regularly anticipated and treated the damage.

Chapter 5 Dolium Use: Functions and Scale

5.1 ***Introduction.*** There several different types of large-scale ceramic vessels that stored agricultural goods throughout the ancient Mediterranean, including amphorae, dolia, *pithoi*, and *seriae*. Of these, dolia were by far the largest. Their enormous size and robustness were both the fruit of a sophisticated set of production techniques that were developed over the course of several centuries. This chapter examines the various ways in which dolia were used. It begins with a general consideration of the use of dolia before presenting the evidence for this from Cosa, Pompeii, and Ostia. Although most dolia were generally wine fermentation and storage vessels, this chapter explores the various ways they functioned and contributed to local and regional agricultural economies. In order to have a better understanding and appreciation of the impact of dolia at the various case study sites, this chapter first considers how dolia were incorporated into their locus of use, such as a storehouse or farm, and what was required to use and maintain them.

Dolia were employed primarily for the fermenting of must into wine and the storage of wine, and their importance in the Roman economy grew during the middle and late Republic along with that of the wine trade. With the acquisition of grain producing regions, such as Sicily, North Africa, and Sardinia, by the end of the Third Punic War, agricultural estates in Italy became larger and began to shift their attention to the more profitable practice of viticulture. From the late third century BCE onwards, dolia appeared in great quantities at farmhouses and villas throughout central Italy. In addition to major ports of trade, some of these production facilities had many dolia. A single farmhouse could be capable of producing 15,000-66,000 liters of wine each year.[300] Italian wines were increasingly regularly traded and sold in far-away places, and in large quantities.[301] The growth of Italian wine production required the widespread adoption of storage containers capable of meeting its demands, a development that we can trace most clearly at Rome and its environs.[302] Various scholars have sought to calculate the annual consumption of wine at Rome during the imperial period, with estimates ranging from a low of one hundred to as much as two hundred fifty liters of wine per person on an annual basis. The supply of this massive amount of wine to the populace of the city of Rome required extensive facilities for its storage and distribution, including, among other things, the construction of specially outfitted wine warehouses along the banks of the Tiber and downstream at Ostia.[303]

5.2 ***Methodology and Aims.*** This chapter takes a different approach from (the little) previous scholarship on dolia. It examines the function and scale of employment of the dolia in their contexts, not only to illuminate the economic role and scale of activities of the settlement, but also to understand dolia's significance within the Roman economy. At the

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[300] De Simone 2017, 37-40.
[301] Purcell 1985, 6ff.
[302] There is a sudden boom of dolia throughout southern Gaul as well starting in the late first century BCE. Carrato 2017 is a recent and comprehensive study of this phenomenon.
[303] Cf. Frier 1983, 257 n. 3; for other estimates of annual consumption of wine and oil per capita, see Marzano 2013, 91 n. 35 who cites De Sena 2005 (20 liters oil, 100 liters wine); Kehoe 2007 (100 liters wine); Purcell 1985, 13 (250 liters wine); Tchernia 1986, 26 (146-182 liters wine).

very least, dolia serve as useful proxy to gauge a farmhouse's annual production, but their presence and use also contributed to and enabled a growing wine industry and urban storage regime. Even though dolia were, in general terms, used for storage of goods, there could have been major differences in their exact function. *Dolia defossa* were often used for the fermentation and initial storage of wine for a farm; even among this function were different scales of production, whether it was for the household's consumption, for sale at the local market, or for more large-scale profitable exports.[304] Wine dolia could have also been used at places of distribution and/or consumption, such as at shops or in bars where people would have consumed the beverages; these dolia were for short-term storage, since wine would eventually turn into vinegar with exposure to air. We will also see that, although dolia were designed as wine fermentation vessels, in some instances individual vessels were employed for multiple functions. Buried dolia were usually for wine and sometimes other equipment can clarify a dolium's function (treading vats, presses, trapetum, etc.), otherwise, it can be difficult to ascertain a dolium's contents without scientific analyses.[305]

The size and capacity of a vessel were important too.[306] By taking into account ancient incisions marking volumes on dolia, studying and processing three-dimensional models generated by a 3D iPad scanner, and applying mathematical computations, this chapter looks closely at the different volumes of the vessels to gauge if there were standard sizes for different functions. A number of the dolia at Ostia and some at Pompeii feature (ancient) incisions on their shoulders or rims that indicated their volumes. As **Chapter 3** mentioned, this project utilized an Occipital structure sensor 3D iPad scanner to generate three-dimensional models of some dolia; these models were then processed and analyzed with software such as MeshLab, Rhinoceros, and/or AutoCAD to calculate their capacities. Other methods this project employed to calculate or estimate vessel capacities as well as clay volume were figures and models generated by the application SketchUp and mathematical computations developed from a collaborative project with Stanley Chang, a professor of mathematics at Wellesley College, and Gina Tibbott, a Roman archaeologist and contemporary potter based in Brooklyn. This chapter also analyzes the general number, placement, and distribution of dolia in the settlement to consider how dolia were transported; which kinds of persons had access to these vessels and their contents; the scale of the settlement's economy; the labor required for their maintenance; and the nature of the relationship between settlements and their surrounding hinterland. By studying the functions, scale, and placement of the dolia in each settlement, this chapter highlights the range of functions and significance dolia could have in different contexts and on labor regimes involved in their transportation, installation, maintenance, and use.

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304 Macrobius *Saturna* 7.12-15: farmers buried dolia to minimize contact with air, which would spoil the wine.

305 As mentioned in the previous chapter, I have initiated a collaboration with a chemistry laboratory at the Università degli Studi di Napoli Federico II; in addition to the ICP-MS we hope to do for metal analysis, we are planning to conduct residue analysis (GC-MS) to identify the contents of dolia.

306 Hilgers 1969, 58: a dolium was a "large bellied vessel" (*grosses, bauchiges Gefäss*) up to 2.75 m in height with the widest part of the vessel at the center upper portion of the vessel, a large opening, and often with a lid.

5.3 ***Acquisition, Maintenance, and Use(s).*** Although craftspeople designed the dolium for wine fermentation and found ways to prevent their vessels from suffering further damage down the road, that was only one aspect of a long story. Acquiring, transporting, installing, maintaining, and using dolia required enormous inputs of labor and coordinated effort every step of the way. This could begin before the dolium was even made. Although people in antiquity had options for where to purchase a dolium, certain production facilities, and even industrial areas, had better reputations than others; since dolia were such expensive investments, dolium buyers likely visited the workshops and selected their purchase with great care.[307] As Anatolios in the *Geoponika* (6.3) advised, these visits should include inspecting the clay source and the dolium itself. On the other hand, ethnographic work on *pithoi* production and distribution in the Messenian Gulf during the 19th and early 20th centuries showed that *pithoi*, in addition to being purchased directly by users at the workshop, could be distributed via local and regional trade, as well as long-distance sea trade to be sold at markets.[308] Many *pithoi* were purchased by locals directly at the workshop, though *pithoi* could be sold at emporia or fairs, directly to merchants who stockpiled them and sold them later, or to ship captains who would transport them and sell them further afield; *pithoi* were often transported by carts though occasionally they were shipped to more distant destinations.

After the dolium was sold, dolium buyers, dolium makers, merchants, or even off-season agricultural workers carefully transported the vessels to their destination, whether by cart, boat, or ship. Dolia found aboard shipwrecks in the Mediterranean demonstrate that some dolia were installed as fixtures of specialized bulk wine transport vessels and sometimes transported by boat or ships to their final destination. As **Chapter 3** mentioned, there were specialized ships in which dolia were permanent bulk transport containers for wine. Ships and boats also transported dolia from their loci of manufacture (fixed urban or rural workshops; or, if made by itinerant potters, close to the usually rural locus of use) further afield to loci of use, such as villas and farmhouses in the countryside and shops, warehouses, and other storage facilities in urban settlements. Ships and boats moved dolia whether it was by sea, as the case with some dolia produced in the Tiber River Valley or Minturnae and then installed in a villa on the island of Elba, or along rivers, which was probably how dolia produced in *opus doliare* workshops in the Tiber River Valley reached Rome and Ostia.[309] Moving these large, heavy, and cumbersome jars in and out of boats and ships was most likely done with cranes installed at ports, and this was probably the most cost-effective method to transport dolia.[310]

Although there were dolia installed at port warehouses, the majority of dolia were transported on land by carts to be installed further inland at urban settlements and agricultural

[307] As **Chapter 3** discussed, by the third century CE, a dolium cost 1000 denarii, while a ceramic vessel with a capacity of two Italian sextarii cost 2 denarii (*Diocletian's Price Edict* 15.97-101); to provide a sense of scale and comparison, a laborer generally earned 25 denarii/day and a head of lettuce cost only ½ a denarius. Cato *de Agri Cultura* 135 names Trebla Alba and Rome as good places to purchase dolia.
[308] Blitzer 1990, 698-707.
[309] Cf. Manca et al. 2016.
[310] Vitruvius *de Architectura* 10.2.10; Wilson 2011, 51.

production facilities.[311] Overland transportation was generally a more expensive way of moving goods, and could be a significant factor, in addition to the cost, size, and quality of a dolium, in one's decision in acquiring a vessel.[312] Cato's (*de Agri Cultura* 22.3) discussion of purchasing an olive mill from Suessa or Pompeii provides useful points on the topic of moving heavy farm equipment. A buyer took into consideration not only the price of the mill itself, but also the price, and mode, of transportation. Moving an olive mill from a local site, Suessa in this case, as opposed to a site further afield, Pompeii, incurred only a fraction of the price as transportation costs (1.44 sesterces/mile versus 3.73 sesterces/mile);[313] moving a mill from Suessa could form up to 40% of the total purchase price, while transporting a mill from Pompeii made up 70% of the total cost.[314] But there was another factor. Eric Poehler, in his discussion of a household or farm transporting their own goods (Household Mode) or contracting drivers (Commercial Mode), brings up several important points:

> At 25 miles distant from his villa, Cato reports the transportation cost for bringing the mill from Suessa was 72 sesterces using six men for six days, while the cost for delivery from Pompeii, 75 miles away, was nearly four times that amount, 280 sesterces. These figures seem to show transportation costs growing dramatically with distance. There is however, an important difference. While the trip to Suessa was a round trip as Cato's own carts were used, making the trip a total of 50 miles, the mill from Pompeii was being delivered. Comparing these costs per mile, the trip to and from Suessa was 1.44 sesterces per mile while the trip from Pompeii was 3.73 sesterces per mile. The difference in price is striking; transportation costs are two and a half times less when one owns the means of transport. Such variance in cost is the economic advantage behind the Household Mode of transport. On the other hand, this same example also demonstrates that the Household Mode was restricted by distance. If Cato had sent his own vehicles to Pompeii, the return trip of 150 miles would have cost 216 sesterces by his figures, or 77 per cent of the cost to have it delivered. More importantly, the time necessary for the trip would have tripled as well, taking away six men and six oxen from other work for eighteen days and delaying the arrival of the mill by nine days. The value of lost production from men and machinery, though not discussed by Cato, would have made the Household Mode of transport less efficient than the Commercial Mode at this distance.[315]

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311 Erdkamp 1999: the seasonality of agricultural labor meant that agricultural workers often also transported their goods to marketplaces. It is possible that they could have transported dolia too, especially if they were the new owners and users of the dolium; see Cato 22.3 discussion on purchasing and transporting and olive mill. Carrato 2017, ch. 3: *tinajas*, traditional wine fermentation containers in Portugal, were transported in mule-drawn carts.

312 Duncan-Jones 1974, 368: "Taking the Diocletianic figures for sea transport and road transport by wagon, the cost ratios for the three types are sea 1, inland waterway 4.9, and road 28-56 (depending on the interpretation of the kastrensis modius)."

313 Poehler 2011, 205.

314 McCallum 2010, 5.

315 Poehler 2011, 205-206.

The acquisition and transportation of a dolium therefore depended on a number of factors: the distance between the locus of manufacture (the workshop) and the locus of use (the vessel's destination); whether the dolium buyer had the resources (vehicle, draught animals, labor) to transport the dolium; and, if so, whether the dolium buyer wanted to use the time and resources to transport the vessel rather than contracting a driver. For buyers who did not have the means to transport the vessel themselves or chose not to, transporting a dolium from further away was thus dependent on the availability of contract drivers and well-connected roads.[316]

In addition to draught animals and a team of laborers, it was also important to have the proper vehicle in order to transport a dolium. The legal weight limits of carriages and carts outlined by the *Codex Theodosianus* indicate that the very large dolia were likely transported in (four-wheeled) carriages, and not carts, due to their heavy weight (**Tables 5.1-5.2**);[317] yet work done on Roman roads and vehicles suggest that two-wheeled carts could bear heavier loads than stated in the *Codex Theodosianus*, and were likely even able to support the weight of and transport a large dolium.[318] Ethnographic work on *pithoi* and *tinajas*, too, demonstrate that two-wheeled carts, pulled by two mules, were sufficient to transport the large ceramic vessels, which workers carefully moved, possibly with ropes and mats, loaded onto the cart, and packed it with straw or other supportive material.[319] Whether dolium purchasers supplied their own draught animals, laborers, and vehicles or contracted the services of drivers, transporting a dolium could add significant costs to the already pricey investment.[320]

Dolium users could have acquired *new* dolia from workshops, and possibly from marketplaces, but there were also various informal channels to obtain *used* or *secondhand* vessels. New owners of farmhouses would also come into possession of dolia and other farm equipment as the property changed hands;[321] dolium owners could also sell their vessels on an *ad hoc* basis when they no longer wanted to use and keep the vessel, and arrange the removal, transportation, and re-installation of the vessel with the new owner. In an episode of Apuleius' *Metamorphoses* (9.5-7), an adulterous wife was able to carry out her affair with the neighbor in the presence of her oblivious husband by selling their old dolium for seven *denarii* to the neighbor. The husband climbed into the dolium to clean it, as the wife and neighbor carried

316 Poehler 2011, 206: Varro (*de re rustica* 1.2.23) also notes the importance of roads and infrastructure of transport for the Household Mode of transportation, and hence the success of a villa.
317 8.5.8: "We ordain that only one thousand pounds of weight may be placed upon a carriage (*reda*), two hundred pounds on a two-wheeled vehicle, and thirty pounds on a posthorse, for it appears that they cannot support heavier burdens" (trans. Pharr).
318 Poehler 2017, 108-109 notes that these figures were likely the legal maximum weight limits for different means of overland transport, probably as an attempt to reduce wear on Roman roads, but should be considered the average, or even minimum, loads.
319 Carrato 2017, 147-152.
320 This might be why people might continue to use old dolia even if they affected the taste of the wine (*Geoponika* 6.3). For discussion of different mechanisms of distribution of sigillata pottery to settlements, cf. Van Oyen 2015b.
321 Cato *de Agri Cultura* 1.4 mentions looking at dolia to gauge production yields when inspecting a farm; *Digest* 33.6.3 and 33.6.15: dolia are considered fixed farm equipment and not expected to accompany wine that is sold.

out their sexual encounter, before hoisting it over his shoulder to carry it away.[322] The *cella vinaria* of the Villa N. Popidi Narcissi Maioris in Scafati preserves only the contours of the *dolia defossa* that were removed in antiquity, probably after the eruption of Vesuvius in 79 CE, providing an example where dolia could be (salvaged and) repurposed.[323]

Whether the dolium was acquired new or secondhand, once it arrived, it had to be installed and stabilized. How exactly a dolium was installed and maintained depended on its (re)use.[324] As **Chapter 3** discussed, dolia were designed primarily as wine fermentation and storage vessels, but were occasionally used for other purposes, including containing other foods or materials, providing shelter, and functioning as an oven or fixture.[325] Evidence for how a dolium was (re)used could come directly from its contents, whether it was found still holding macro-remains, such as dolia containing carbonized legumes and grains from the villa N. Popidi Narcissi Maioris, or from the analysis and identification of incrustations or absorbed organic residues, such as the *dolia defossa* from the *cella vinaria* of the so-called Villa of Augustus in Somma Vesuviana.[326]

Direct evidence is not common, however, so much of what we know come indirectly from different forms of evidence: contexts that indicate their use; modifications on the containers; and statements from textual sources. The context or locus of use is probably the most common form of indirect evidence. Dolia found buried in courtyards known as *cellae vinariae* were used for the fermentation and storage of wine, while dolia for storage could be found in warehouses or storerooms known as *horrea* specialized for the storage of liquids;[327] dolia built into the hulls of ships were bulk wine containers for transport overseas. Dolia could be (re)used to hold other goods and have been found built into shop counters to hold dry foods, installed in gardens to collect water as part of an irrigation system, and placed at sites of construction to hold building materials.[328] The vessels themselves could bear signs of how they were used. Dolia were sometimes modified for particular functions, such as altering or removing the rim to enlarge the vessel's aperture or cutting the vessel to use portions as a

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322 I thank Mahmoud Samori for bring this to my attention. Although the dolium of this passage was moved off by the husband, and suggests that the dolium was not too heavy for one man to carry, this could be an exaggeration to highlight the husband's misfortunes.

323 De Spagnolis 2002, 273-274. It is also possible that the dolia were removed after the earthquake of 62 CE.

324 For overview on prime use of dolia, see Peña 2007a, 46-47.

325 For overview on reuse of dolia, cf. Peña 2007a, 194-197.

326 De Spagnolis 2002, 273-274: four dolia from Villa N. Popidi Narcissi Maioris contained carbonized organic materials, including *Vicia faba*, *Triticum*, *Vicia ervilia*, and *Lathyrus sativus*. Allevato et al. 2012, 401ff.: vats and dolia from the so-called Villa of Augustus at Somma Vesuviana were confirmed with the analysis of organic residues using gas chromatography-mass spectrometry (GC-MS) to have been used for wine production. For general discussion of GC-MS to detect wine, cf. Pecci et al. 2013.

327 For several examples of *cellae vinariae*, see De Caro 1994; Fentress 2017; De Spagnolis 2002; Jashemski; Carandini 1985. For several examples of *dolia defossa* in storerooms in Ostia, see Rickman 1971, PG; Paroli 1996. For dolia in *cella vinariae* and in storerooms in Gaul, cf. Carrato 2017, 277-590.

328 Dolia have been repurposed as containers in counters at various properties in Pompeii including VII.9.54, ETC. For dolia on holding plaster, cf. Jashemski 1993, 139; Cheung and Tibbott forthcoming.

basin, well head, or reused as building materials.[329] Textual sources are also highly informative. The *Digest* (Iul. *Dig.* 50.16.206) indicated that dolia no longer containing wine should not be classified as pressroom equipment and instead could be used for storing other foods such as grain, while Manilius (*Astronomica* 5.676-9) said, in describing catching tunny, large amounts of net-caught fish could be placed in *Bacchi dolia*. Vitruvius (*de architectura* 7.12.1) noted that dolia could be used as a furnace in the industrial processing of lead.

Fig. 5.1. Depiction of viticultural equipment management, from Rustic Calendar mosaic at Saint-Romain-en-Gal. The farmhands, probably slaves, are probably preparing to move a dolium for cleaning.

[329] De Caro 1994, 123: a dolium bottom was likely used as a basin for feeding chickens. Jashemski 1993, 55: the upper portion of a dolium was used as a puteal. Dolium rims were used in building the opening of a kiln in Spain (pers. comm. Lynne Lancaster).

How exactly a dolium was used determined its installation and maintenance. In Vitruvius' (6.6.2-3) discussion of the set-up of a farmhouse; the oil dolium was usually placed in a south facing room, whereas wine dolia were installed in a north facing courtyard. The lone dolium or dolia for oil at a farmhouse was usually unburied, but wine dolia were usually clustered and buried to their shoulders as *dolia defossa* in a courtyard, a process that must have been laborious and time-consuming. Pliny (*NH* 14.27) noted that wine dolia in regions with warmer climates were buried (and we see this in Italy), but were not interred in colder climates in the north. To install wine *dolia defossa*, hundreds of liters of earth must have been removed in order to install a single vessel. The differences in treatment and labor between oil and wine dolia extended to their maintenance as well.[330] Oil dolia were cleaned with hot water and lye and their interior surface coated with wax or gum only periodically, while wine dolia were cleaned and coated with pitch, usually pine resin, before each harvest, so at least once on an annual basis, otherwise the wine would be adulterated from the unclean, used containers.[331] Maintenance for wine dolia was especially onerous. For buried wine dolia, farmhands undertaking the task had to climb into the dolium with a torch to scrape off the previous layer of pitch, scrub and clean the vessel, and, after the vessel dried, apply a new layer of pitch (**Figs. 5.1-2**); they also had to be careful not to place the torch too close to the vessel, otherwise it could damage the dolium, or even cause it to burst.[332] This was not a task without difficult and even hazardous conditions. Farmhands, who were probably slaves, climbing into these vessels could be knocked unconscious, or even killed, by the intense odors of residual sediments and were advised to check the safety conditions with a flame first.[333]

Fig. 5.2. Depiction of pitching a dolium, from Rustic Calendar mosaic at Saint-Romain-en-Gal. The farmhands are lining the dolia with pitch heated in a smaller container on the right.

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330 For overview of cleaning and resurfacing dolia, see Peña 2007a, 211-213.

331 Columella 12.52.14-17 on cleaning and coating oil dolia; Columella 12.18.5-7 on cleaning and coating wine dolia, a task Columella states has to occur 40 days before each harvest.

332 Columella 12.18.5-7.

333 Pliny *NH* 23.3.1.

As **Chapter 2** discussed, using dolia was laborious too. Although dolia were important wine fermentation and storage vessels, they were employed in connection with one in a long chain of actions that brought wine from farm to table. After freshly pressed must was placed in the dolia, the vessels were usually left uncovered for several days. After the first phase of fermentation, dolia were sealed with a pitch-lined lid (*operculum*) and then protected with an outer lid (*tectorium*) on top.[334] Because dolia were fixed, farmhands had to transfer the wine to other containers after it fermented. Farmhands would manually siphon, pump, or even ladle the wine from dolia into skin or ceramic containers, a time-consuming and repetitive job given that many dolia would hold several hundred, even over a thousand, liters of wine. Cleaning, pitching, repairing, filling, and emptying wine dolia were all strenuous tasks that were usually done before, during, and after the grape harvest, an already intense period of grape picking and pressing.[335] But these tasks were essential for protecting both the contents and the vessels themselves.[336]

Since dolia were such expensive and valuable equipment, they were expected to last a long time. **Chapter 4** discussed the different methods dolium repairers used to prolong the use of dolia. It is unclear how long these vessels were in use, but they were probably expected to last for several decades. Ancient sources do not mention how long these vessels were in use, but their 'life expectancy' probably changed over time as dolium production and repair techniques improved. Contemporary vintners say their *tinajas, talhas*, and *qvevri* are used for more than a century, and some even claim their vessels date back to the 17th century, while vintners using concrete or ceramic eggs say they can be in use for at least fifty years, far more than a barrel.

Regardless of how successful these repairs and interventions were, however, dolia almost always inevitably fell out of use or broke completely, both offering and requiring additional avenues for informal secondhand exchange and trade. Dolia could be broken beyond repair, perhaps from cracking during the fermentation process, and no longer suitable for its primary or original intended use or contaminated by their contents to the point that the vessels were deemed no longer useable.[337] Dolia could also fall out of use when the facility in which they were located was abandoned, or if the activity for which they were used was no longer practiced. As mentioned above, people were able to find different ways to retain the vessel's value, from reusing the vessels as containers to modifying them for entirely different purposes. Dolia and other large ceramic storage containers could store fermented fish products, grain, legumes, nuts, other dry foods, and even non-food items, while damaged dolia

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334 Cato *de Agri Cultura* 11.2; Taglietti 2015, 276ff. Examples of these lids have been found at Villa Regina at Boscoreale (De Caro 1994, 63-69), Villa Settefinestre (Celuzza 1985, 59), and at Pompeii (unpublished materials in the San Paolino Deposito). The *operculum* was typically a flat cover with a loop handle, while the *tectorium* was a slightly convex disc with three trapezoidal pegs or legs to support the *tectorium* atop the *operculum*.

335 The Menelogium Colotianum and the calendar from Santa Maria Maggiore indicate that dolia for new wine were pitched during the month of September; Degrassi 1963, 284-298; Magi 1972, 1ff.

336 Even ripening grapes needed protection in Roman Egypt, cf. Helms 2013.

337 *Geoponika* 6.3: people could continue to use old containers but it would diminish the quality of the wine.

could be reused for construction.[338] Because dolia were such enormous architectural fixtures, even deciding *not* to use them required their proper removal or altering the room entirely.

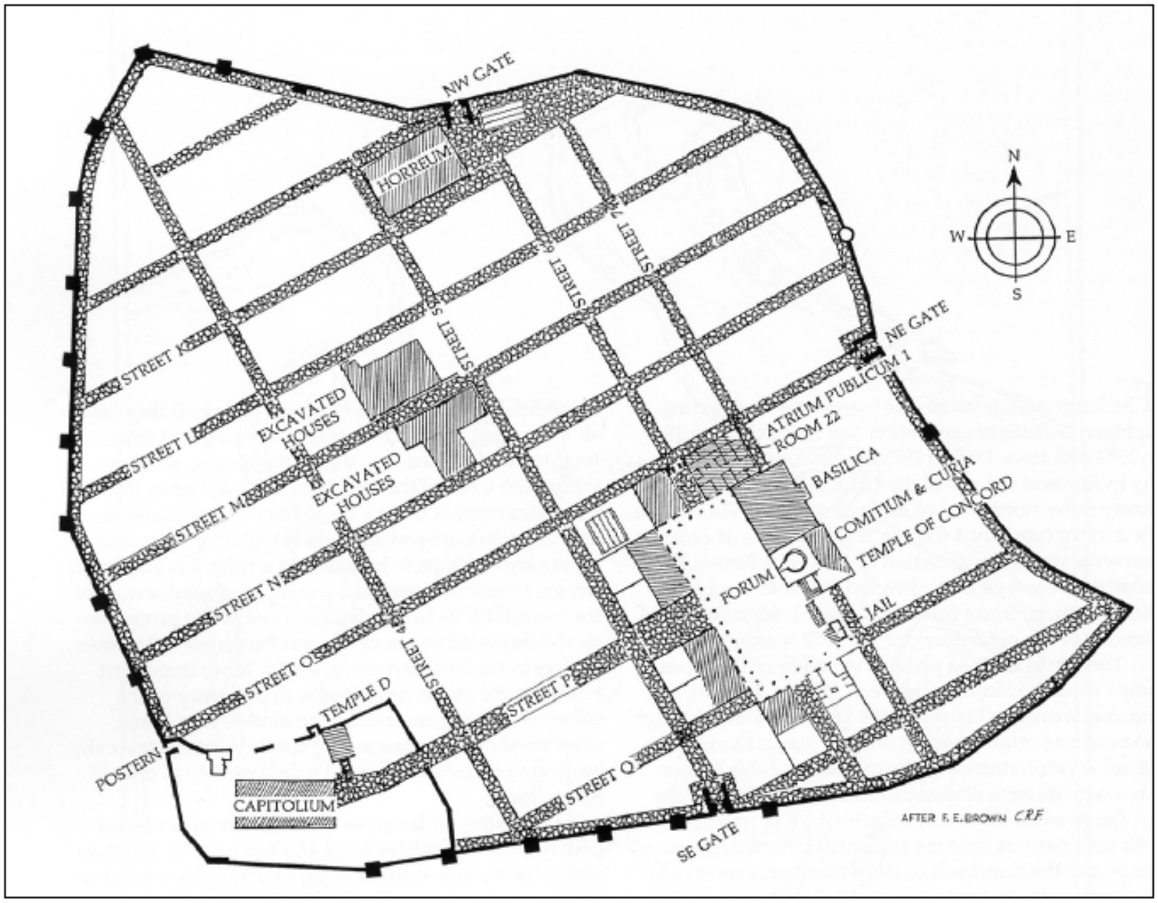

Fig. 5.3. Plan of Cosa. Most dolium fragments were found near the Capitolium and in houses.

5.4 ***Cosa.*** Many of the c. 50 dolium fragments from Cosa date to the middle of the second century BCE to the first quarter of the first century BCE and almost all were found in contexts of reuse of architectural fill to build a defensive, artificial terrace on the Arx between the Capitolium and the town walls at the end of the first quarter of the second century BCE (**Fig. 5.3**);[339] near this area was a gate in the walls that led to an area where the town's waste was deposited, perhaps where people retrieved refuse to reuse as architectural

338 *Digest* 50.16.206. For how dolia were reused, cf. Peña 2007a, 194ff.

339 Five or six dolia and fragments were reused as fill (consisting of material from the middle of the second century BCE to the first quarter of the first century BCE) to form an artificial terrace on the Arx between the Capitolium and the town walls by the end of the first quarter of the first century BCE. For brief summaries, cf. Moevs 2006, 7ff.; Scott 2008, 1-6, 177-179. Slane forthcoming Appendix 1: the deposit has been interpreted as "'clean-up' after a sack by pirates ca. 70-60 BC" and as evidence the site was fortified against raids of Sextus Pompey in the 40s BCE, but might have been part of the Augustan reorganization of the site.

fill.[340] Since almost all the dolia were found in reuse contexts, it is difficult to provide precise information as to where and how they were originally used. Of those found in what was probably their primary use contexts, they were found in large atrium houses and their gardens, such as the House of the Skeleton, probably to store wine, grain, or other foods for the household.[341] Dolia must have also been useful for storage, especially in food shops, and there was one large dolium in a shop by the Forum that probably contained wine and a dolium rim fragment found in the town's putative horreum.[342]

Because of their fragmentary nature, it is impossible to calculate the volumes of the vessels, but the rim fragments give a sense of their scale. These ceramic storage containers were of varying sizes and, as **Chapter 3** discussed, with only a few dolia with seemingly standardized rims. The small- and medium-scale storage vessels, which probably had capacities of c. 20-150 liters, were likely used for the household's storage of grain, olive oil, or wine.[343] The few large dolia with enormous rims comparable to the largest dolia of Pompeii likely had capacities of c. 300-500 liters and were probably used for the storage of wine for local consumption.[344] The wine was likely brought in from Cosa's hinterland, which was dotted by large estates actively engaged in for-profit, export-driven viticulture during the Republican period.[345] Although the amphorae evidence testifies that the wine was exported as far afield as Gaul, surely some of it arrived to Cosa too, where there were several large dolia well suited for wine. The owner of the dolium could have purchased wine from the estates (or also owned the wine-producing estate) in bulk quantities and then sold the wine in smaller amounts. The dolia could have been for communal storage of wine and were perhaps owned by the town or by a single or group of owners who leased its use.

Although there were not many dolia at Cosa throughout the course of the settlement's history, when they were in use, they helped link the town to its hinterland. While wine bottled in amphorae could be transported into the town on a cart in limited quantities, an amphora's

340 According to Frank Brown's excavation notebook, explorations outside the city walls revealed a refuse dump that was never published or studied. Poggesi 2001 discusses the restoration project of the Cosa walls, and the discovery of an entryway in the wall. I thank Kevin Dicus for this reference.

341 Several unpublished dolium fragments and lids come from the House of the Skeleton.

342 Brown et al. 1994, 106; Brown 1984, 495-497.

343 These had an interior rim diameter ranging from 15-30 cm.

344 The only dolium fragment large enough to give a sense of the volume is Cosa no. 19, which is comparable in size to the large dolia of Pompeii (c. 500-700 liters). Only nine dolium rim fragments were of this scale.

345 Cosa was an urban settlement, dominated by public spaces, such as the Forum, Basilica, Horreum, and numerous temples, but there were a number of atrium style houses too. Russell and Bruno 1993, 1 states that approximately two-thirds of the settlement was for public works. Although these atrium style houses had gardens, the properties were not large enough to support vineyards for viticulture. It was unlikely that some wine was made the gardens since no press has been identified in any of the houses. Cosa's limited water supply probably could not support the cultivation of vines for wine production. Fentress et al. 2003, 17ff: the garden in the House of Diana was a kitchen garden presumably for vegetables.

The literature on viticulture in the *ager Cosanus* is vast, see Manacorda 1978; 1981, 1980; Rathbone 1981; 1978; Dyson 1978; Carandini 1985; Carandini and Cambi 2002.

shape was not efficient for overland transport.[346] Instead, merchants likely transported wine in animal hide skin containers on carts, decanting the wine into a different container(s) at the destination. Wine was probably usually poured into individual containers one by one, but a single, large dolium meant that wine could quickly be decanted. The large dolia in the town could have been used for short-term storage to expedite the transfer process, but the access to this product might have been limited and restricted; if the dolium belonged to a single owner, s/he probably purchased wine in bulk, likely by the *culleus,* and stored the wine in the dolium until s/he decided to sell the product, perhaps when prices were more favorable. The wine would then be packaged into smaller vessels for sale and distribution.

There are several possible reasons why Cosa had such low numbers of dolia. One is related to the archaeological work at the site. Previous excavations might not have documented properly, or even identified, dolia and dolium fragments. Furthermore, with only a small portion (c. 15-20%) of the ancient town excavated, more dolia could remain to be discovered. On the other hand, the settlement's hilltop position (114 meters above sea level) could also be why the number of dolia at Cosa was low, and why broken dolia were reused frequently in architecture as fill. Dolia were expensive vessels, and their large size and limited portability augmented their worth, so damaged dolia at Cosa were often repaired, modified, or reused to prolong their functionality. With the town perched atop a steep hill, it must have been difficult to transport dolia to their destinations. Dolia made from inland workshops would have been transported one by one on a cart into the town, whereas those made in workshops near a water source were probably transported by boat to the port and then by cart up into the settlement.[347] Since this must have been the case for bricks and tiles, discarded ceramic and terracotta materials were often reused for architectural projects, reducing the need to transport building materials uphill to the site.[348] Besides the difficulties posed by Cosa's elevated position, the scarcity of dolia could also be due to the sparse population's low demand for bulk quantities of wine.[349] Although there were shops that sold food and beverages at Cosa, they were not numerous or widespread;[350] it was difficult to support and justify vessels requiring high inputs of labor and recourses.[351] Furthermore, if there were not

346 Cf. McCormick 2012.

347 It was possible, though highly unlikely, that itinerant potters visited the site and constructed storage vessels on the spot, especially for the very large, spherical dolia. Although constructing the vessel on site would have eliminated the problem of transporting the finished vessel, other logistical challenges would arise. Large amounts of clay (probably at least a couple hundred kilograms) would have to be transported to the site; the potter would have to stay on site for the course of several weeks to build the vessel, build a kiln, and fire it (the vessel would also require weeks to dry before being fired).

348 For discussion on this matter based on reuse of amphorae in vaulting, Lancaster 2005, 68-85.

349 The second draft of colonists was sent to Cosa in 197 BCE. Livy 39.55: the population of Cosa was already low enough by the late second century BCE that additional colonists were sent to Cosa. This trend in dwindling population continued, and became even more decimated during the imperial period.

350 Brown 1993.

351 Georgian *qvevri* are manually cleaned, requiring several hours, or even a day, just to clean and scrub; Barasashvili 2011, 17-19: many *qvevri* are soaked for a day before a lime mixture is dissolved inside the vessel for three hours and then scrubbed multiple times; Diggory 2018: cleaning a *qvevri* takes a full day with a traditional brush. For dolia, it would have required additional time to repitch the vessel after it dried over the course of a few days.

many consumers in the town, was not a strategic decision: the dolium's wine would turn into vinegar if not consumed within a short period of time.[352]

The inhabitants of Cosa practiced not vast, bulk storage, but storage that was more individualized and fragmented from its countryside. While many large dolia in the *ager Cosanus* were used to ferment wine and store wine and oil in bulk quantities at production facilities, the town itself had different storage practices that likely used amphorae and other smaller-scale vessels.[353] Overall, the dolia of the town were mostly out of use by the mid first century BCE, with only a couple dolia dated to the first century CE. Unlike Ostia and Pompeii, Cosa did not have a bustling population or retail landscape and, certainly by the first century CE if not earlier, it was not a common destination, fading into the hazy landscape of southern Tuscany that became mostly forgotten.

5.5 *Pompeii.* Dolia and other large ceramic containers were important containers and architectural elements at Pompeii and were well preserved and found in great numbers around and within the urban settlement itself (**Fig. 5.4**). Because Pompeii was primarily an agro-manufacturing town in a fertile landscape, these jars, dated to the first century CE, were widely used for numerous agricultural activities and processes, such as the fermentation of wine and the storage of various foods. As a result, the distribution of dolia and other types of storage jars in Pompeii is widespread, and the storage vessels, numbering over two hundred still accessible for study today, are found in-situ in farmhouses, vineyards, gardens, orchards, shops, bars, and houses.[354] Most of these storage vessels were found in-situ, providing context and evidence for prime use at the time of the eruption in 79 CE, but a small number of dolia and dolium fragments come from earlier contexts securely dated to the first half of the first century CE.[355] There were two distinctive types of ceramic storage jars at Pompeii: the dolium, which was ideal for the storage of liquid products, and a

352 Today, people are advised to consume wine within 3-5 days of opening the bottle; fortified red wines, however, can last up to one month. Ancient wines stored in dolia were probably lower in quality and similar to contemporary table wine, and did not have a long shelf-life; furthermore, a dolium's shape, especially its large upper portion, meant more wine was exposed to air (to use *talhas*, vintners add a layer of oil which sits on top of the wine to prevent oxidation, and wine is drained from the bottom of the vessel).

353 Villa Settefinestre is an exemplary production facility in the ager Cosanus, cf. Carandini 1985. A workshop producing amphorae, bricks, tiles, and coarseware pottery was located less than 15 km north of Cosa in the modern town of Ansedonia; see papers in Vitali 2007. Slane forthcoming, the town of Cosa had large quantities and several types of amphorae, including imports, that spanned several centuries; a diachronic history of amphora use in Cosa suggests that the town (and its port) was initially an export center, but during the first century BCE, it increasingly became a consumption site, which might explain why there are almost no dolia in the town during the imperial period. I thank Kathleen Warner Slane for sharing her manuscript.

354 At least fifteen dolia recovered from the earliest excavations were removed from their contexts and have since been placed elsewhere and were not accessible for this study.

355 The *dolia defossa* of the Villa Regina at Boscoreale were installed during its Augustan phase, De Caro 1994, 118; several (unpublished) dolium fragments were found in a midden by Tower 8 at Pompeii, which had no accumulated material beyond 50 CE, Romanazzi and Volonté 1986, 57; Peña and Cheung 2015, 2119-2120.

cylindrical jar not seen outside the Vesuvian region, possibly associated with the *seria* mentioned in ancient sources, which was optimal for the storage of dry goods and as architectural elements built into bar counters (**Fig. 5.5**).[356] Although this project focuses on dolia, cylindrical storage jars were often found together with dolia in Pompeii. These vessels were produced in particular sizes by design and were installed and used in various contexts; often dolia and cylindrical jars are used together, and sometimes interchangeably, in vineyards and bars. For this reason, this chapter looks at both the strawberry-shaped dolia and cylindrical storage jars to understand the role of ceramic storage vessels at Pompeii.

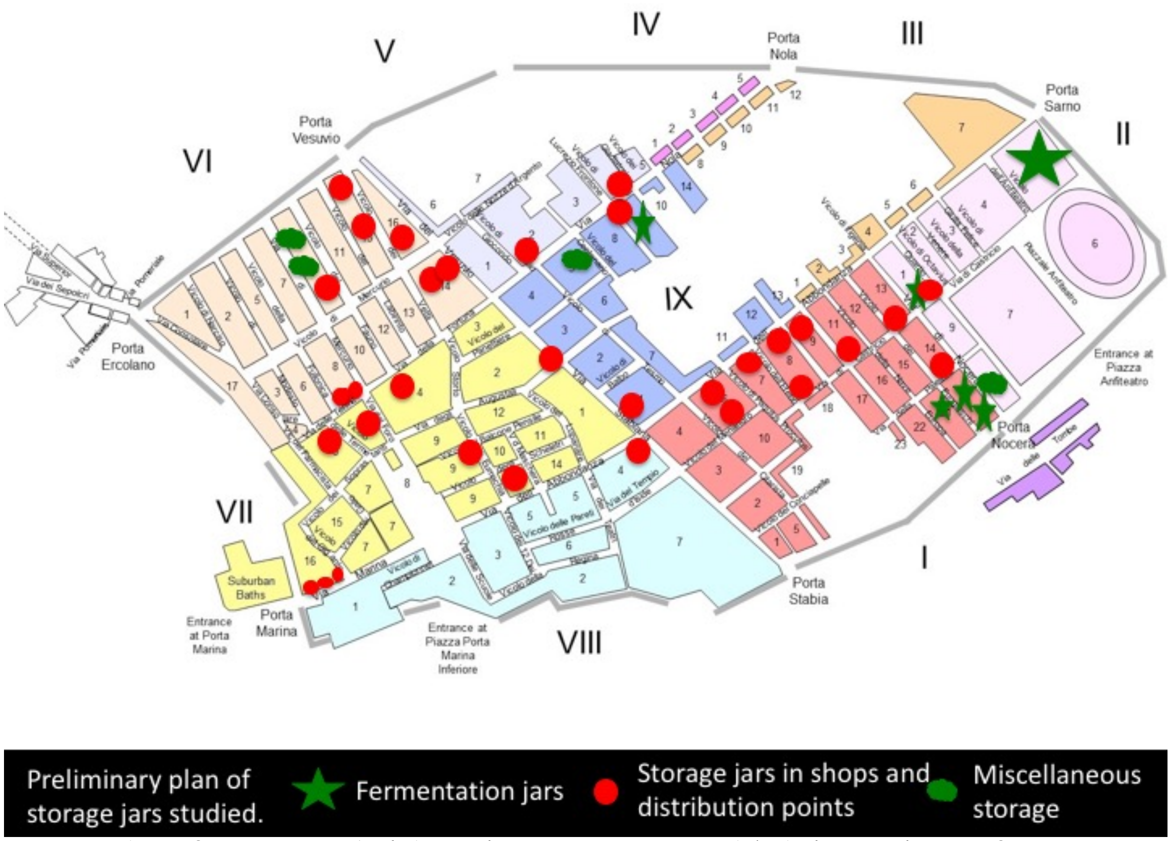

Fig. 5.4. Plan of Pompeii with dolia and storage containers labeled according to function.

356 The production and repair cylindrical jars of Pompeii will be discussed in greater detail in a forthcoming article-length project that discusses food storage and storage jars in Pompeii.

Fig. 5.5. Example of a cylindrical jar, possibly a *seria* or *orca* in Latin texts, (I.6.8), Pompeii.

Pompeii had a number of green spaces and agricultural production facilities throughout the town, some of which were dedicated to the production of wine and to a service and hospitality industry; properties with identified vineyards, whether based on vine root cavities or the presence of treading or press equipment, included the Caupona of the Gladiators (I.20.1); a shop-house garden (I.20.5); the Garden of the Fugitives (I.21.2); the large vineyard by the amphitheater, formerly known as the *Foro Boario* (II.5.5); the House of Aemilius Primio and Aemilius Saturnius (II.1.8-9); a partly excavated vineyard (III.7); the House of D. Caprasius Primus (VII.2.48); the house of a wine-seller (IX.9.6/10); and the Villa of the Mysteries just outside the town walls.[357] Over 20% of all dolia, and all the largest dolia,

[357] The vineyards of Pompeii were compiled based on Jashemski 1979a, 1993 and the website pompeiiinpictures.org. All properties listed, with the exception of III.7, have dolia in-situ that formed part of this study. The vineyard of III.7 was only partly excavated; Jashemski 1979a, 228-232; 1993, 104-105; Della Corte 1965, 367. Meyer 1980, 418. For information regarding: the Caupona of the Gladiators (I.20.1), cf. Jashemski 1979a, 178, 227-228; 1993, 67; Maiuri 1959, 83-87; Orr 1972, n. 53; Elia 1975, 134-135; the shop-house garden (I.20.5), cf. Jashemski 1977, 217-227; 1979a, 188-194; 1993, 67-68; the Garden of the Fugitives (I.21.2), cf. Jashemski 1979a, 243-247, 249-250; 1993, 69-70; the House of Aemilius Primio and Aemilius Saturnius (II.1.2, 3-7, 8-9), cf. Jashemski 1993, 75. Orr 1972, no. 55. Bragatini 1981, 209; the large vineyard by the amphitheater (II.5), cf. Jashemski 1968, 69-73; 1970, 63-70; 1973a, 27-41; 1973b, 821-830; 1979a, 201-218; 1993, 89-90; . Maiuri 1928, 43. Meyer 1980, 418. Fiorelli 1864, 150; the House of a *Vinarius* (IX.9.6/10), cf. Jashemski 1967, 193-204; 1979a, 221-226; 1993, 246-247. Boyce 1937 91, nos. 458, 459. Niccolini 1896, 33-35. Pernice 1932, 53. Sogliano 1888, 514ff.; 1889, 123-125. Mau 1889, 15, 19-20, 27; 1890, 228-231. The dolia of the House of D. Caprasius Primus (VII.2.48) are no longer in-situ, Jashemski 1993, 175. Niccolini et al. 1862, 45. Brizio 1868-9, 90-91. Breton 1970, 419. Fiorelli 1873, 37; 1875, 198. Warscher 1935-1960.

in this study are found chiefly at these properties.[358] Regiones I and II were excavated relatively recently in the course of Pompeii's archaeological projects (20th century), and several excavations were conducted by Wilhelmina Jashemski, who utilized Giuseppe Fiorelli's plaster cast technique to create casts of root cavities in order to identify plants that were growing at the time of the eruption; Jashemski's work has shed light on the town's viticulture, gardens, and other plantings. Portions of Regiones I, III, IV, V, and IX are unexcavated, and it is possible that more agricultural areas, and dolia, remain buried.

There were, of course, many wine production facilities outside of Pompeii, such as the Villa Regina and Villa Pisanella at Boscoreale, the Villa of N. Popidius Narcissus in Scafati, among others. Wine production facilities were planted with vineyards, some of which still preserved root cavities of the vines, and often had equipment such as a wine press or vat and large fermentation dolia, the largest dolia found in town (**Table 5.3**).[359] Not only was the shape of these vessels well suited for the fermentation process, but their size was also ideal for storing large batches of wine, even long-term storage perhaps to hold the wine until the market was favorable.[360] For example, the ten dolia of the vineyard by the amphitheater (II.5.5) were capable of holding c. 10,000 liters of wine.[361] The Pompeian fermentation dolium's size (the average was c. 550 liters, about one *culleus* worth of wine) might have been a strategy to buffer against risk of failure, both in dolium production and during the fermentation and storage of wine, and for facilitating transfer between containers (dolia and *cullei* especially).[362]

Food and drink establishments were found throughout the town of Pompeii, and the majority of ceramic storage containers, both dolia and cylindrical jars, can be found at these properties.[363] The cylindrical jars, and occasional dolia, in masonry counters ranged in size and capacity, from under 100 liters to over 500 liters. A number of jars in masonry counters had modified rims that featured two sets of iron pins or rods drilled into the rim, 180 degrees from one another. These iron pins might have been used to help secure a lid, especially if it were an object modified as a lid, such as a tile or thick cloth.[364] Workers at these shops generally stored a variety of dry foods such as nuts, legumes, grains, and vegetables inside these ceramic

358 Several dolia of this study were reused at the time of the eruption in the large orchard (I.22), which was planted as an olive grove; cf. Jashemski 1979a, 251-261, 372, 382; 1993, 73; Cheung and Tibbott forthcoming.
359 All the properties mentioned in the previous footnote featured large dolia, with the exception of I.20.1, which had several, large cylindrical jars. For discussion of the archaeology of these spaces and the identification of these ancient plantings, cf. Jashemski 1979a, 1993.
360 Cato *de Agri Cultura* 3.
361 Jashemski 1968, 73; 1973, 36.
362 Many things could go wrong, including the wine turning into vinegar (Frier 1983) and the dolium cracking leading to a loss of wine (Varro *de Re Rustica* 1.13.6).
363 Cf. Ellis 2004, 2018. I thank Steven Ellis for sharing proofs of his monograph, which has been particularly relevant for this chapter.
364 Some examples include vessels at V.4.6-7, VI.8.11, VI.8.8, VI.14.36, IX.5.11.

storage containers; sometimes they placed several containers of different kinds of foods inside the ceramic storage vessels, which acted as a pantry for various goods.[365]

Fig. 5.6. Set of cylindrical jars in bakery (IX.1.3), Pompeii.

In constructing these alimentary shops and bars, construction workers built masonry counters *around* the vessels *after* installing them.[366] To do so, the person tasked with overseeing these establishments, whether it was the owner or a managerial figure, procured all the vessels that s/he wished to incorporate before construction began.[367] The jars of a bar were almost always a homogeneous set of jars of similar sizes and shapes, suggesting that cylindrical jars of similar, perhaps standardized, dimensions were widely available (**Fig. 5.6**). Most of the vessels

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365 Ellis 2018, 229: "lentils were recovered from a bronze vessel at I.3.11, along with turnip seeds in a ceramic pot; in I.11.10–12 cooked beans and an unidentified vegetable were found in a bronze vessel; onions, beans, and shellfish were recovered in the excavation of V.4.7; legumes were reportedly found in the counter at VI.2.5; shellfish were recorded in one of the five bars in insula VI.16; at VII.12.15, lentils; legumes at IX.7.21–22; and shellfish in the bar at IX.11.2. To these we can add some examples at Herculaneum: carbonized grain was identified in the dolium of the counter at IV.10; the counter at V.6 was found to contain beans and chickpeas; grains and legumes were found in the dolia of the counter at IV.15–16; grains, chickpeas, and beans were in association with the counter at II.13; and bowls heaped with walnuts are said to have been found on the counter at IV.17–18." See also Packer 1978, 47-48; MacMahon 2005, 81ff. The discoveries and finds at Herculaneum and Pompeii were probably all 'staged' though; I thank Joanne Berry and Steven Ellis for bringing this to my attention.

366 Ellis 2018, 53-54; MacMahon 2005.

367 As Ellis 2018, 26 rightly notes, studying these architectural fixtures as "products, or 'outcomes,' of a set of complex agencies in urban investment [can] reveal much information about the social, economic, and even political motivations behind the development of economic portfolios and the creation and maintenance of the retail network." Dolia and other ceramic jars fed into investment of urban retail and food and drink establishments during the first century CE, a period Ellis has identified as a 'second retail revolution' tied to the urban boom of the early imperial period.

built into the masonry service counters fell within the category of middle range cylindrical jar (capacity of c. 120-200 liters); only a handful were large cylindrical jars or dolia. The large cylindrical vessels had very wide rims and mouths and thick walls, and they could hold twice as much as the mid-sized jars typically found in the counters.[368] The large jars could hold great quantities of food, and they were generally reserved for especially grand shops in heavily frequented areas, such as the Thermopolium of Vetutius Placidus (**Fig. 5.7**). Only very occasionally did shop owners install dolia in masonry counters (**Fig. 5.8**); dolia, with their round and irregular forms, complicated the construction process of these counters. Moreover, they were also generally more difficult to make than the cylindrical jars, and probably more expensive, so dolia were often reserved for wine fermentation and storage. The few bar counters with dolia, including the Thermopolium of Vetutius Placidus, were probably damaged and rebuilt after the earthquake of 62 CE using second-hand dolia that had also been damaged and were no longer fit for wine storage and fermentation.[369] Building masonry counters *around* these damaged dolia offered structural support so the vessels could be repurposed and still provide thermal insulation for storing and preserving dry foods (**Fig. 5.9**).

Fig. 5.7. Thermopolium of Vetutius Placidus (I.8.8), Pompeii. From pompeiisites.org.

[368] The largest cylindrical jars could hold at least 300 liters, whereas the average capacity of a medium cylindrical jar was c. 150 liters.

[369] The best evidence for the reuse of dolia in bar counters is found at VII.9.54, where a bar counter was built around several very large dolia that were broken and/or cracked.


Fig. 5.8. Masonry counter of bar with dolia installed (VII.9.54), Pompeii.

Fig. 5.9. Detailed view of interior surface of damaged and reused dolium installed in bar (VII.9.54), Pompeii.

Fig. 5.10. Shop with buried ceramic jars (VI.14.36), Pompeii.

Many of these food and drink establishments also featured smaller dolia that were partly or fully buried (**Fig. 5.10**); these vessels were of two sizes, one a smaller vessel and the other a more mid-sized vessel.[370] Medium-sized dolia were commonly buried in shops near the bar and were probably used as short- to medium-term storage containers for wine or for dry goods. Shops with these dolia could buy local wine that was brought in a skin container from the countryside or a vineyard in Pompeii, rather than buying amphorae of wine.[371] Small dolia and cylindrical jars (capacities of 40-80 liters) were never found in isolation; they were usually partly buried near larger dolia, cylindrical jars, or other types of equipment such as grain mills, suggesting they were short-term or temporary storage containers in food processing. The small jars in bakeries, for example, could have temporarily stored flour as the mills were running before it was placed into larger vessels or sacks (**Fig. 5.11**).[372] Overall, the smaller dolia and jars could be used in alimentary establishments for multiple uses to supply fresh foods.

370 I considered smaller dolia go have at most a capacity of 150 liters, whereas mid-sized dolia had an average capacity of 250 liters.

371 Wine in shops could also be stored in amphorae, and might explain why only some shops had dolia. Examples of bars in Herculaneum and Pompeii, such as the Thermpolium of Asellina (IX.11.2), show that wine was sometimes kept in amphorae.

372 Alternatively, they could have held small batches of wine that a shop could sell probably in just a few days' time before the wine would turn.

Fig. 5.11. Bakery with different set of ceramic storage jars (VII.16.4-7), Pompeii.

Houses, on the other hand, typically did not have dolia or other storage jars. There were only a few gardens in which large ceramic jars were found, and they all seem to have been repurposed. In the Garden of Hercules (II.8.6), three large, repaired dolia, which were probably originally used for wine, had been installed as part of an irrigation system in the commercial flower garden.[373] Several dolia, pools, basins, and a cistern collected rainwater and were linked by channels that divided the garden into beds situated on a slope. One of the vessels, mounted onto a small base at the time of the eruption, is the most heavily damaged and repaired vessel in all of Pompeii (**Fig. 5.12**). The dolium maker must have noticed cracks forming during the production-phase and added double dovetails and the extensive clamp-hybrid repairs, but the damage on the vessel was probably still so alarming, that the owners decided it would be more prudent to stop using it for wine fermentation, if it was ever used for fermentation at all. At the House of Meleager (VI.9.2), inhabitants used a cylindrical jar, probably to store food in one of the rooms;[374] in the garden, however, construction workers repurposed an enormous dolium, probably also initially used for wine fermentation, as a

373 Jashemski 1979a, 267-288; 1979b, 405-406; 1993, 94-96; Meyer 1980, 432. Jashemski considered "the remarkable watering system in this garden by far the most elaborate yet found at Pompeii" (1979b, 406).

374 The vessel does not preserve any macro-remains or other evidence that offer direct evidence for its use.

container for lime during renovations at the time of the eruption.[375] Likewise at least six large and three small dolia were also re-used to store construction materials during renovations of the House of Stabianus (I.22), perhaps to repair damage from the earthquake of 62 CE (**Fig. 5.13**). The absence of these food storage vessels in residential settings suggests that they were too expensive to be considered general household items, that households stored food in modest amounts that would not require a large jar, and that residents instead visited shops and bars on a regular basis to buy fresh food.[376]

Fig. 5.12. Dolium repurposed for irrigation, from the Garden of Hercules (II.8.6), Pompeii.

Fig. 5.13. Dolia repurposed for construction activity, at House of Stabianus (I.22), Pompeii.

[375] Jashemski 1993, 137.

[376] Cf. Ellis 2018, ch. 7. Before households in China were equipped with refrigerators and gas stoves and ovens, people went to the market daily for fresh foods and relied on their local shops for prepared foods. This is still how many households in China operate, see Strickland 2016.

Ceramic storage jars of all sizes were found throughout the town, providing extensive infrastructure for the production, storage, and distribution of different foods. Although only some houses had ceramic storage jars on-site, the abundance of dolia throughout the town in bars, shops, and taverns gave residents and visitors to the town regular access to the agricultural products at these various distribution and commercial spaces. The distribution and placement of these vessels, however, were not random. Bars could be found throughout most of the town, primarily clustered along the major thoroughfares, but were largely absent in quieter, less frequented zones, like more posh, residential area of Insula VIII, just south of the Forum. On the other hand, wine fermentation dolia, and wine production facilities, remained at the margins of Pompeii in the green zones where large plots of land were available (again), where the smells of wine production could be isolated, and where dolia could be transported easily.[377] Pompeii had a close relationship with its hinterland, and the dolia and other storage jars further blurred the distinction between town and country by facilitating agricultural production and storage in the town.

To install and maintain this system of supply and distribution, however, required a tremendous command of resources and steady stream of manpower and coordination. For places such as the Thermopolium of Vetutius Placidus (I.8.8), with thirteen large jars, and the so-called *Foro Boario* (II.5.5), which had at least ten large dolia, this was a serious investment not only in financial resources, but also time and effort.[378] Most, if not all, the vessels must have been brought into the town on carts through the town gates, and with many dolia installed in Regiones I and II, the Porta Sarno and Porta Nola were probably common passages through which dolia and jars arrived.[379] The sea was probably another, though less often used, avenue for these massive vessels to reach the town. Some of the largest vessels, with production stamps that indicate they were produced in workshops in northern Campania and southern Latium, are found on the western end of the town and were probably brought in from the sea.[380] The primary mode of transportation, however, was by cart. Workers had to arrange and pack carefully the vessels in the carts; for large dolia and jars, workers probably moved them one by one, but they might have been about to transport smaller cylindrical storage jars in pairs.[381] From more distant workshops, this was an especially significant

377 This zone of Pompeii was developed later than the rest of the town. Many row houses were built in the zone but were later replaced with gardens and vineyards; cf. Nappo 1997. Around Regiones I and II were large roads, wider open spaces, and two gates, the Porta Nocera and the Porta Sarno. Ann Olga Koloski-Ostrow's forthcoming monograph identifies this area as one where many malodorous activities and industries were relegated.
378 Vessels at these properties were almost always a heterogeneous set. Although some of these assemblages could have been collected piecemeal over time or incorporated second hand vessels, it is most likely that these mixed assemblages reflect the limited availability of these vessels.
379 For wheeled traffic in Pompeii, cf. Poehler 2017, 2011.
380 Steinby 1981. These include dolia in the Villa of the Mysteries and the cylindrical storage jars at VI.8.9.
381 Cf. Carrato 2017, ch. 3 for discussion on how contemporary dolium-like vessels are moved.

investment due to how expensive overland transport was, and also because there was always a risk the vessels would break.[382]

Owners or managers of properties planning to install storage vessels likely procured the right number, type, and size of jars before they could be installed and incorporated into the property. For vineyards, these would be the largest dolia in the area the owner could find, capable of holding 500-750 liters. To acquire such large vessels that weighed over 500 kg each probably required transporting the dolia one by one and carefully packed on the *angaria*, a four-wheeled vehicle drawn by teams of horses, oxen, or mules that was the most capable vehicle for heavy hauling (**Tables 5.1-2**).[383] Moreover, for dolia placed in specialized *cellae vinariae*, workers building the room likely took into account the vessels as they designed the room and constructed the room around the dolia after they had been buried. For example, the *cella vinaria* of the vineyard at the so-called *Foro Boario* (II.5.5) was a small, narrow room with lead pipes connecting to the adjacent wine press room. The dimensions and layout of the *cella vinaria* suggest that builders constructed the rooms only after the dolia were installed and aligned with the lead pipes, and it was probably impossible to fit a dolium through the narrow doorway. For cylindrical jars and the occasional dolia in masonry counters, workers set up the vessels and then built the counters around the jars. Many properties had homogenous sets of vessels, but it was also common to find different vessels together; owners might have been limited to whatever vessels were available at different workshops, find a second-hand jar, or add vessels after the initial set-up.[384]

The amount of labor and resources for this system extended beyond the production, transportation, installation, and repair of these massive ceramic storage vessels. Even the daily use and maintenance of these containers placed a heavy demand on different laborers. To move wine, vineyard workers had to transfer the wine from the dolia, presumably with a siphon, pump, or ladle, into *cullei* for overland transport or into amphorae. Merchants likely sold the contents of *cullei* to local alimentary shops, where wine would be transferred from the *cullei* into the shop's buried dolia. Merchants could have also shipped amphorae overseas or distributed them to urban food and drink establishments. For dry goods, workers brought in legumes, nuts, grains, vegetables, and other foods in sacks or baskets and transferred them to the shops, where shop employees stored the foods in the storage containers. This process must have occurred regularly in order to supply fresh foods and wine throughout the town. In addition, workers had to maintain and clean these storage jars on a regular basis to ensure the freshness and quality of their contents. For vessels containing dry goods, this likely entailed periodic inspections of the vessels and removal of old contents. But this was an especially strenuous process for wine containers, where workers had to remove old resinous material and scrub, rinse, and dry the vessels thoroughly before adding a new layer of pitch coating,

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382 For discussion regarding overland transport costs in Cato *de Agri Cultura* 22.3, see Poehler 2011, 205-208.

383 Weller 1999 "Wagon Construction": *Angariae* had a center or draught pole and their wheels had 12 spokes. They are probably similar to German farm wagons built in the early 20th century.

384 Examples include I.21.2; I.22; I.20.1; I.20.5; Villa of the Mysteries.

which would have required more than a week to treat wine production dolia in Pompeii alone.[385]

Fig. 5.14. Triclinium by *dolia defossa* in vineyard of Inn of the Gladiators (I.20.1), Pompeii.

Transporting, installing, using, and maintaining dolia and cylindrical jars involved different, often high, levels of costs, risk, and payoff, and their use at Pompeii were important for feeding the town and adding to the town's service and hospitality industries. Wine fermentation dolia were equipment characteristic of the countryside, whereas cylindrical jars were important storage units for distribution centers that provided urban dwellings access to fresh foods. Large dolia were placed in the 'green zone' of the town not only to produce and store wine, but also to bring elements of the country into the town; they were often placed within view of customers enjoying wine on a triclinium (**Fig. 5.14**). Their use in Pompeii highlights the 'producer' nature and rural activities of an agro-manufacturing town, with strong ties to its hinterland.

385 With c. 30 *dolia defossa* at wine production facilities in Pompeii, it would have required 30 vessels x 3+ hours of cleaning/vessel = 90+ person hours just to clean the wine fermentation dolia at Pompeii (https://kargigogoblog.wordpress.com/2016/05/02/qvevri/ accessed April 13, 2018); based on contemporary evidence of *qvevri* cleaning (Diggory 2018), one vessel would have taken a whole day to clean with a brush, so 30 vessels x 1 day/vessel = 30 person days of labor. If smaller dolia at shops were also used for wine, they would have had to be cleaned and relined with pitch often for every new batch of wine.

5.6 ***Ostia.*** In the early second century CE, the settlement of Ostia underwent major renovations and expansion, including the installation of at least four storehouses with some of the largest dolia in the ancient world (**Fig. 5.15**).[386] These rooms and their specialized storage equipment, totaling approximately 200 dolia, were installed by or just shortly after the first quarter of the second century, providing massive storage facilities for wine and possibly also olive oil. The dolia were enormous (average capacity was 1,008 liters) and packed close together in the storerooms to maximize space; altogether, the dolia of Ostia were estimated to have contained well over 100,000 liters of liquid commodities.[387] Unlike Pompeii, Ostia's dolia were not for the production of wine. Ostia was *not* an agricultural town and its immediate hinterland does not appear to have supported intensive viticulture. Instead, Ostia's dolia, much larger in size, were storage containers for wine and possibly oil that had been produced elsewhere and brought into the city for distribution across the center of the Roman Empire.

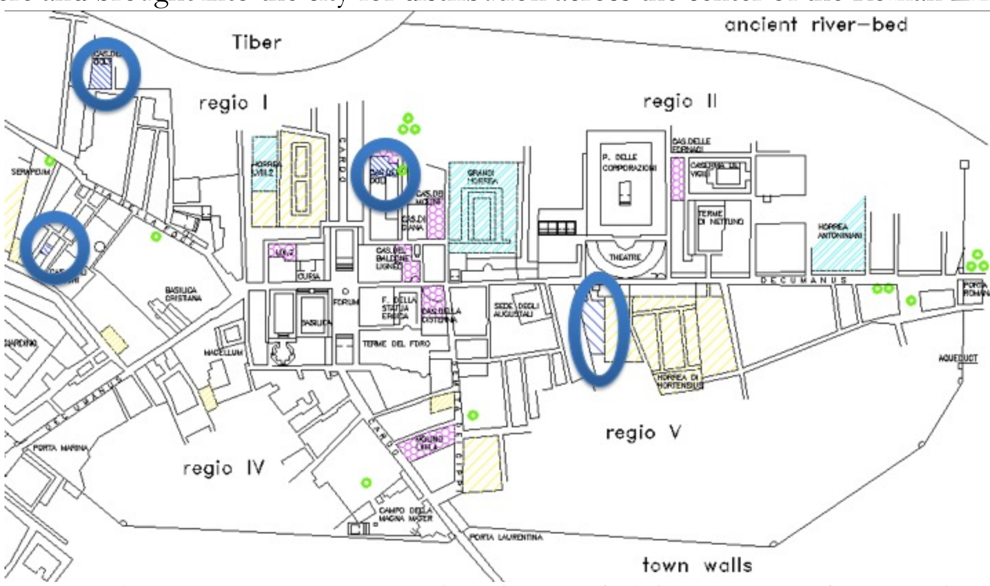


Fig. 5.15. Plan of Ostia. Storerooms with *dolia defossa* – dark blue, encircled; horrea for grain – light blue; other store buildings – yellow; bakeries – purple; millstones – green. Adapted from www.ostia-antica.org.

386 Rickman 1971, 73-76, dating of the storerooms mostly based on construction technique and brick stamps. Giornale degli Scavi Notes for Magazzino Annonario (V.6.5) July/August 1939 notes that a dolium lid with a stamp (*CIL* 1013), dated to 108 CE, was found. Dating of these storerooms also based on construction materials and techniques, and fit well with the rest of the city that had been renovated in the second century CE. Paroli 1996 reports a fifth storeroom with *dolia defossa* that was partly excavated with test trenches, but its date of construction is uncertain.

387 Rickman 1971, 75ff; Gatti 1903. Based on the volume incisions, the average dolium contained 33 amphorae. Although the dolia were about the same size and probably had similar ceramic fabrics, indicating close proximity among the workshops, three of the warehouses were probably for wine while the Magazzino dei Doli was likely a storehouse for oil. It was originally connected to the house of an individual named Annius, who portrayed himself as a merchant of oil or wine and is likely the attested oil lamp producer Annius Serapiodorus; cf. Ceci 2001, 2003. The dolia themselves were not originally buried in antiquity (though they are now buried because floor of the room has been raised), suggesting that they stored oil. It would be interesting to excavate the dolia and see whether oil dolia were labeled the same way as wine dolia.

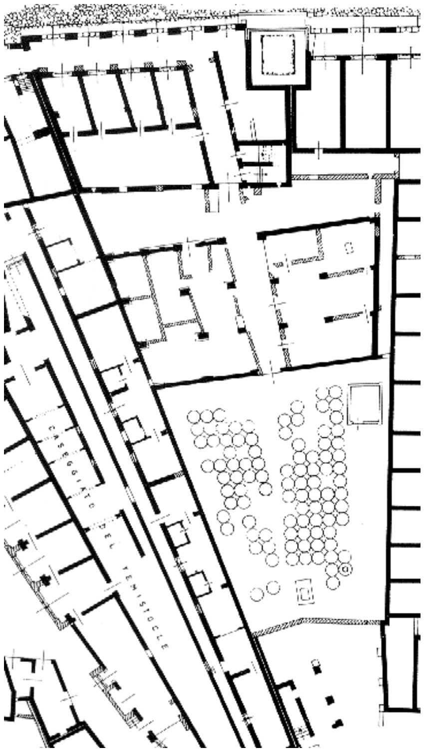
The dolia at Ostia were enormous storage vessels clustered in just a few storerooms whose primary purpose was to hold liquid agricultural commodities, probably for a short period before a portion was repackaged for further distribution whether it was within Ostia or upriver to Rome. Ostia's function as the port of Rome is underscored by the number of warehouses that appear to have served for the storage of food destined for distribution to the city of Rome. The Ostian dolia were probably brought to the city first by river on boats from the *opus doliare* workshops located in the Tiber River Valley upstream of Rome, and then loaded on carts to the storehouses. The storerooms of Ostia were generally positioned on or by major thoroughfares. They were associated with different types of buildings and each had a different form of access, suggesting that each of these facilities probably had a distinct function. The main entry to Magazzino Annonario was just behind a portico and set of rooms on the decumanus by the Porta Romana (**Fig. 5.16**). Since it was far from the river and close to one of the city gates, we can conjecture that it served for the storage of wine brought to Ostia overland, probably in *cullei*, for the supply of its inhabitants.[388] Not far from the Tiber River, the Magazzino dei Doli was connected to the House of Annius and probably stored wine or oil for Ostian residents (**Fig. 5.17**); the dolia there were probably *not* buried to their shoulders as *dolia defossa* in the second century.[389] On the other hand, the two Caseggiati dei Doli were originally along the Tiber River in antiquity and could have received wine from the specialized dolium boats, via pump, siphon, and/or an intermediary container, potentially eliminating the need for amphorae for that step of the process (**Figs. 5.18-19**).[390] The wine and oil at these storehouses along the Tiber could have been for the Ostian residents, who generally lived in densely occupied high-rise apartments that did not have storage areas, or could have been stored briefly at Ostia before being sent to Rome.[391]

388 For discussion of wine and oil production in Rome's hinterland and why it is difficult to detect archaeologically (lack of amphorae and presses), cf. Marzano 2013; De Sena 2005. See also Rickman 2002, 358.

389 The dolia are now buried, but the low threshold of the room suggests that the floor level of the room was raised after the second century CE, perhaps in an effort to repurpose the room.

390 Pasqui 1906, 357-373: By the late second and early third century CE, the dolia of the Caseggiato dei Dolii near the museum were filled in with terracotta molds and earth and covered over.

391 For discussion of general housing and specific types of apartments in Ostia (and Rome), cf. Hermansen 1981, ch. 1; DeLaine 2004; Storey 2001, 2002, 2004; Packer 1967, 1971. Stevens 2005 has calculated that the apartments had four stories. Evidence for housing in Rome is poor and limited by comparison, but a few apartment buildings featured dolia, probably for the communal storage of wine.



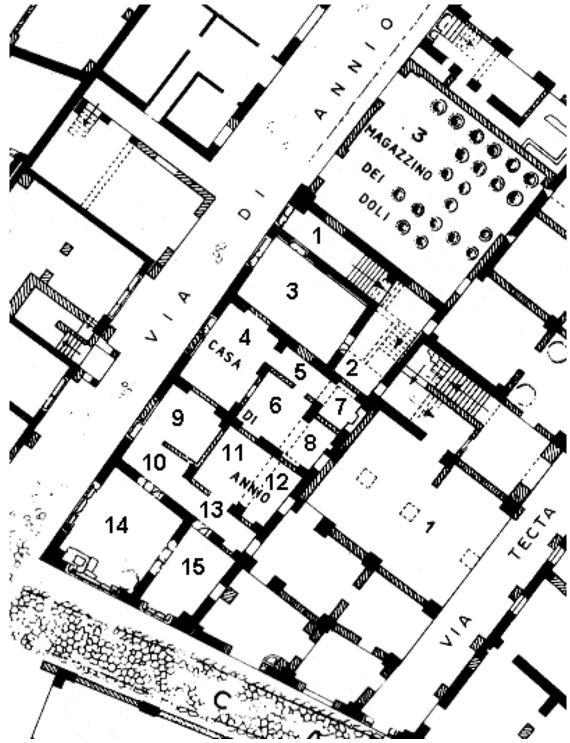
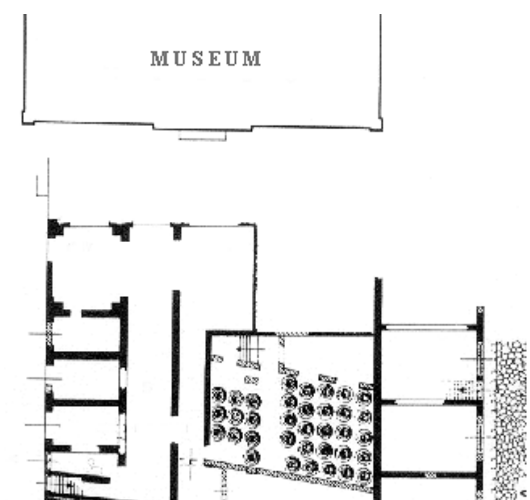


Fig. 5.16. (L) Plan of Magazzino Annonario (V.6.5), Ostia. From www.ostia-antica.org.
Fig. 5.17. (R) Plan of House of Annius, connected to the Magazzino dei Doli to the north (III.14.3), Ostia. From www.ostia-antica.org.



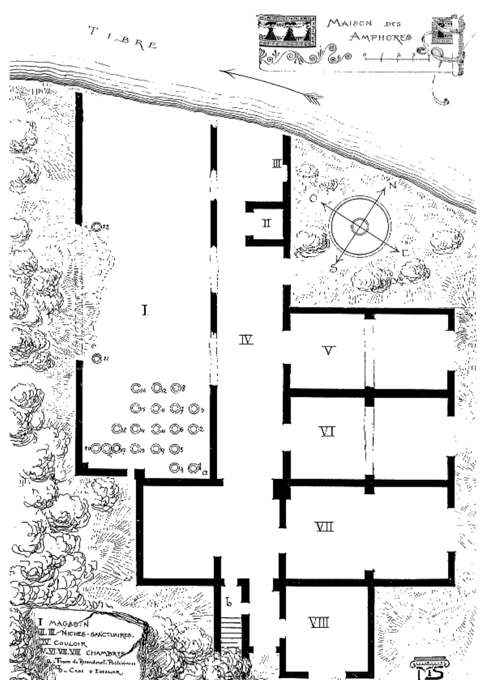


Fig. 5.18. Plan of Caseggiato dei Doli (I.4.5), Ostia. From www.ostia-antica.org.
Fig. 5.19. Plan of Caseggiato dei Doli (near I.19), now reburied, Ostia. From www.ostia-antica.org.

Installing and maintaining such a sophisticated storage regime at Ostia, especially with several, major contemporaneous renovations, required planning and significant and constant inputs of resources and labor at every stage. This started as early as dolium production, when dolium makers enlarged the vessels. This investment in producing larger vessels was not a simple, linear increase in the size in the amount of materials used. Even for just the dolium lids, a dolium lid of 70 cm diameter required twice as much clay material as a lid of 50 cm diameter.[392] Dolium makers formed large dolium rims that facilitated the regular maintenance required for the upkeep of the storage vessels. Because they probably stored multiple batches of wine every year, the dolia of Ostia must have been cleaned and recoated with pitch several times a year, perhaps before each new batch of wine was placed in the containers. This process, surely lengthy and laborious, was important for the wine's quality, and probably required thousands of hours of work.[393] Workers climbed inside the dolium for the routine inspection, and any necessary repairs, of the vessel. The dolia of Ostia were incredibly robust, but regular upkeep to seal any minor cracks that could form was important for ensuring the dolia were always available for use. These enormous dolia, though very demanding of resources and labor, were essential for guaranteeing Ostia's, and perhaps Rome's, food supply.

Many of the Ostian dolia feature incisions on their rims or shoulders of Roman numerals to mark their capacities in units of amphorae, with fractional amounts expressed in units of *sextarius* (1/48th the volume of an amphora, or 0.546 liters).[394] The preserved capacity incisions show that the Ostian dolia had an average capacity of over 38 amphorae, a little over 1,000 liters.[395] Most, if not all, of the dolia at Ostia stored wine; while a large number of storage jars were inserted into service counters at bars or used primarily for the production of wine in Pompeii, all the dolia at Ostia were embedded in storerooms. If we try to compare the scale of vessels used for primarily *storage* purposes, then the discrepancy is even greater (**Table 5.3**). Although the average volume for a Pompeian dolium used for fermentation is around half the capacity of a dolium from Ostia, Pompeian dolia used for the same purpose, that is primarily for *storage* and not fermentation, have a capacity of only 20% of an Ostian dolium. This size of Pompeian storage dolia was probably an appropriate size for short-term wine storage at shops and bars. But if these dolia were all used for *storage* purposes, why was the discrepancy in volume so great? Wine storage in Pompeii primarily occurred at shops or food and drink establishments, and storage vessels could hold small batches of wine to be

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392 Dolium lids were usually 3+ cm thick. A 70 cm diameter lid would have required 1.15 liters (thickness x radius squared x 3.14 = 0.003 m x 0.35^2 m x 3.14) of clay whereas a 50 cm diameter lid would have required 0.59 liters (thickness x radius squared x 3.14 = 0.003 m x 0.25^2 m x 3.14) of clay.

393 If we assume a vessel required three+ hours to clean, a one-time cleaning of 180 dolia (the dolia of Ostia, not counting those in the Magazzino dei Doli since they might have stored oil) would have required 540 hours, not including the time to dry and repitch the dolia; the wine dolia probably contained multiple batches of wine each year.

394 Gatti 1903.

395 The volume of a medium or large dolium at Pompeii was 400 to 750 liters, and the largest dolia were reserved for the fermentation process; the Ostian dolia were capable of holding twice the amount. Rickman 1971 gives 33 amphorae for the average dolium volume based on incisions also from the Caseggiato dei Doli that has been reburied. Based on the incisions I have seen, the average capacity was more than 38 amphorae.

consumed in a short period of time. The Ostian dolia, however, were installed in large quantities, concentrated in a handful of purpose-built storehouses that were not (easily) accessible; the dolia's use, regulation, and access were more controlled, limited, and systematic.[396] The large amount of wine in these dolia also meant its removal had to be timed and executed in such a way that the wine could be rebottled or consumed within a short period of time.[397] Workers likely opened the dolia only when they were ready to transfer a significant portion, if not the entire content, of the vessels, whether into *cullei* or smaller ceramic containers such as amphorae or other jars, to minimize the contents' exposure to air.

In order to facilitate this process, the capacities of the dolia at Ostia were clearly marked. In the three of the four *cellae vinariae* still accessible today, each dolium with its rim and shoulder preserved and visible featured an incision of its volume in Roman numerals in units of amphorae with fractional amounts on the vessel shoulder, and occasionally on the rim as well (**Table 5.4**).[398] The texts featured Roman numerals ranging from XXIII to XLV, sometimes followed by other figures such as S or Ɔ, which were in turn occasionally followed by Roman numerals II or III; Gatti, the first to publish these volume incisions, determined that the first set of Roman numerals was in units of amphorae, the symbol S indicated half an amphora, and Ɔ was in units of *sextarii,* 1/48 an amphora.[399] The only dolia of this study without a volume incision were those with rims and shoulders broken and no longer preserved, suggesting that all the Ostian dolia in these storerooms were likely inscribed with these capacity inscriptions in antiquity. The frequency, precision, and scale of these capacity incisions bring to light a conventional system of establishing and designating the volume of each vessel. Since these are most likely post-cocturum incisions, it is impossible to ascertain whether the *opus doliare* workshop or the users did this, but both possibilities are interesting to consider. If the *opus doliare* workshops executed this, it meant that they manufactured the vessels and verified their volumes at the end of the production phase. This was perhaps a way to promote their merchandise. Someone looking to buy a large dolium might purchase from

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396 Rickman 1971, 76 suggests that these storerooms were central storage areas for residents who lived in an urban city too dense for their own storage space. Because they lived in *insulae* apartment blocks that did not have adequate storage areas, "storage for liquids tended to be concentrated at specific points and the storage capacity available could be quite considerable." Some of the storehouses' distance from the Tiber River suggests that the stored goods might have been for local consumption, and not for further trade to Rome.

397 As Frier 1983 notes, this was could be a problematic outcome as early as just after the production process; a buyer was expected to taste the product before the transaction would be complete.

398 The dolia at the Magazzino Annonario (V.11.4-5) and the two Caseggiati dei Doli (I.4.5; I.19) were incised, but it is unknown whether the dolia at the Magazzino dei Doli (III.14.3) were incised since they are now buried to their rims. 25 dolia had their rims and shoulders both preserved and visible, with incisions sometimes on *both* the rim and shoulder.

399 For volume incisions at I.4.5, cf. Gatti 1903, 201-202; at I.19, cf. Carcopino 1909; 359-364. Some dolia were incised with volume in units of *urnae* at the Villa Regina at Boscoreale; cf. De Caro 1994, 68ff. Compilation of dolium capacity incisions in Italy, see Carrato 2017, 709-714. Dolia in Gaul were labeled with capacity figures in Roman numerals in units of amphorae and *sextarii* or in units of *urnae*; cf. Carrato 2017, 186-194, 653-704. Reused amphorae in the northwest provinces were incised with Roman numerals, probably in *modii* and *sextarii*, to indicate their capacity to store dry foods; cf. Peña 2007a, 130-131; Van der Werff 1989, 2003.

an *opus doliare* workshop that boasted its dolium that could hold forty amphorae of wine. On the other hand, a dolium buyer might be looking for a dolium that could hold thirty to thirty-five amphorae worth of liquid contents. Moreover, establishing and labeling the dolia with their volumes may have also simply been an expectation for the urban *opus doliare* workshops. These workshops produced the largest and most robust dolia and might have also provided the additional service of volume control. On the other hand, if the users of the *cellae vinariae* incised the containers, they took the task of checking and labeling vessels' volumes into their own hands. Before the installation of the dolia, then, dolium users measured and labeled each dolium; because the volume format was the same at the two Caseggiati dei Doli and the Magazzino Annonario, the *cellae vinariae* at least shared a system of identifying and labeling capacities of storage vessels, and could have been owned or at least operated by the same personnel, perhaps personnel who were working under or with the praefectus annonae, the corpus mensorum, or other officials overseeing the food supply.[400]

Labeling the dolia must have been important for the transfer of wine into and from the dolium into different containers. Because Ostia was an important pivotal point for the movement of goods from the sea into Rome, the dolia were instrumental in the regular transfers of different foods. Wine either entered Ostia in amphorae, in *cullei* carted from the countryside, in dolia aboard specialized wine-transport dolium boats, or in a combination of the aforementioned methods.[401] Wine brought in by *cullei* or specialized dolium boats would have been transferred from those containers into the *dolia defossa* in the storerooms, and it was possible, but probably less likely, that workers poured out wine from amphorae into the dolia.[402] Oil was probably brought into Ostia in *cullei* in carts, then transferred to dolia in the storerooms. The units of volume in amphorae suggest that amphorae were likely involved in at least one end of the process, or at least factored into calculations.[403] Porters moving goods in Ostia would later open the dolium in order to transfer the wine or oil from the dolium into amphorae and/or skins to move the product, whether to shops and bars in Ostia where wine

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400 For an overview of the imperial administration over the food supply, see Mattingly and Aldrete 2000, 151-153. There were several imperial officials who "formed a coherent unit encompassing Portus, Ostia, the Tiber, and Rome itself" such as: *praefectus annonae* and his *adiutor*, *sub-praefectus annonae, procurator portus, procurator annonae Ostis, adiutor praefecti annonae ad horrea Ostiensia et Portuensia, procurator Augusti ad annonam Ostis, curatores alvei Tiberis et riparum* and their *adiutores, procurator ad oleum in Galba Ostiae portus utriusque, cornicularii, dispensatores, beneficarii,* and *tabularii*. Although these officials were primarily responsible for overseeing grain, they were also involved with the procurement and storage of olive oil and wine (even before they were added to the dole), building and maintaining port facilities, et al.

401 Heslin 2011; Rice 2016: Shipwreck evidence suggests that these specialized wine container ships with dolia cemented in their hulls were only in use from the late first c. BCE through the following century. The *dolia defossa* of Ostia could have been installed as part of a modified packaging system.

402 If wine for Ostia was being imported in amphorae, the collective weight of full amphorae could have been more than the wall could support; transferring wine from the amphorae into dolia could have expedited the process and saved space. I thank Kim Bowes for this suggestion.

403 On the other hand, olive oil was generally weighed and the weight could easily be converted to volume.

and oil could be sold to be decanted and sold directly to consumers perhaps in courtyards of *horrea*, or to Rome itself.[404]

Fig. 5.20. Bar in Ostia, with *dolium defossum* for wine, House of the Thermopolium (I.2.5), Ostia. From www.ostia-antica.org.

Horrea with dolia for the storage of liquid products were not particularly common. Most storerooms with dolia were typically associated with production facilities such as farmhouses or large country villas; these rooms were generally uncovered courtyards in the middle of a building, adjacent to the wine press or the wine pressroom. Ostia's storerooms, on the other hand, were completely divorced from the production process. Unlike Pompeii, Ostia had no equipment or space for the production of wine; there were no vats, wine presses, vineyards, or farmhouses in the town. Even outside the town the land was not suitable for agriculture or viticulture. The wine that Ostia stored must have come from elsewhere and were probably brought in from the hinterland of Latium in *cullei* and from overseas in boats and ships. Consequently, Ostia's dolia and storerooms were used exclusively for storage in a densely developed urban environment. There were only a few lone dolia installed elsewhere in Ostia, primarily in bars to store wine or other liquids (**Fig. 5.20**).[405] Although their numbers

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404 Delaine 2005: horrea were not only for the storage of goods, but could also function as marketplaces.

405 For survey of these bars in Ostia, cf. Hermansen 1981, ch. 4. The cylindrical jars of Pompeii are not found in Ostia. For possible reasons why, cf. Hermansen 1981, ch. 5 (moral code). Another, not

are low, we should think of them as participants in the same packaging system as the dolia in the various storerooms. While dolia in the storerooms stored bulk quantities of wine and oil, dolia in these bars were important hardware for the distribution of foods and for the supply of various services, including the sale of (hot) water (**Fig. 5.21**).[406] Within the history of construction in Ostia, imperially commissioned and supported warehouses for grain were built during the first century CE.[407] On the other hand, the history of storehouses with *dolia defossa* closely followed the fate of densely occupied *insula* apartments, which were constructed at the beginning of the second century but fell into decline less than a century later. Whether the dolia in the storehouses stored wine and oil that supplied the residents of Ostia or Rome, they supported the raising level of urbanism in the Mediterranean by ensuring adequate amounts of foodstuffs.

Fig. 5.21. The "water seller" relief near Tomb 154 of the Isola Sacra, Ostia. From Ellis 2018.

But dolia were not found at all urban areas with ports. There have not been any dolia found at Portus or Puteoli, perhaps because these ports received products and goods differently; both ports received large amounts of grain, while incoming wine was likely

exclusive reason, is that it was too costly and challenging to maintain the jars and dry goods were instead stored in sacks.

406 The relief, at Isola Sacra, depicts a salesperson standing at a counter, with the inscription LVCIFER/AQVATARI(VS), and two jars hanging above a counter on the left hand side of the plaque. In the center is a woman who is facing the left with a small jug in her hand. On the right hand side is a man standing behind a dolium with a small jar in his hand. The plaque seems to show the man on the right moving water out of the dolium into smaller jars that the woman is bringing to the person behind the counter, perhaps to heat before packaging in the jugs above. For discussion of services that shops and bars provided, including Lucifer, the (hot) water seller, cf. Ellis 2018, 236ff.

407 For discussion of grain storage and urban growth in Ostia, cf. Vitelli 1980.

packaged in amphorae.[408] Other settlements with storerooms with *dolia defossa* for wine storage include Rome and parts of southern Gaul such as Marseilles, suggesting that *dolia defossa* for the storage of wine were crucial for urban ports connected to both the sea and a river.[409] Rivers offered a more economic and faster method to transport wine and oil further inland, and various points along these routes were equipped with ports, warehouses, and other facilities where goods could be unloaded and distributed to local communities. Although the evidence is too scant to form any concrete conclusions, the concentration of dolia in these purpose-built storerooms might have been part of a strategy to simplify the packaging system by reducing the number of (bulky) containers involved: wine or oil could come into the city in *cullei* or dolia in dolium ships, be transferred and deposited in dolia in the storerooms, and then be distributed again in *cullei* or repackaged in (reused) amphorae or other jars.[410]

5.7 ***Conclusions.*** Dolia were important storage vessels, not only for farmhouses and vineyards, but also for urban centers. For densely populated settlements, dolia became part of the urban landscape and facilitated bulk movements and storage of goods from the countryside for the towns and cities. Although the sites of Cosa, Pompeii, and Ostia all possessed dolia, many of which were large wine dolia, the functions and economic significance of these vessels differed from site to site. The three sites represent different regions within west-central Italy and, to some extent, different moments in time that reflect distinctive degrees of development in the Roman wine industry and perhaps also other industries. The differentiated storage regimes of west-central Italy at these three sites show a development in the dolium's importance within a growing economy, especially at consumer sites, and reveal differences in the nature of the relationship between urban settlements and their hinterland.

Over the course of its often-intermittent occupation, Cosa, a marginal port town with significant wine production in its territory, had only a few dolia, almost all of which predate

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408 Portus and Puteoli were known as important warehouses for the annona's grain, and archaeological remains at Portus suggest the warehouses were built to house grain and possibly other dry goods; cf. Pagliaro et al. 2014. Because there were shipping challenges for large vessels at Ostia, only smaller vessels could go there, while Portus was later built to accommodate larger shipments; we should think of Ostia and Portus being complementary to one another and that certain vessels and cargoes entered one port more often than the other; cf. Keay 2012, 39ff. Wine was probably sent to Puetoli, at least, in amphorae (*TPSulp* 80).

409 For overview of port facilities, including warehouses, along the Tiber in Rome, cf. Castagnoli 1980, 35-42; Keay 2012, 33-67. For the *cellae vinariae Nova et Arruntiana* in Rome, cf. Fiorelli 1880, 127-128, 140-141; Rodríguez Almeida 1993, 259; Richardson 1992, 80; Carafa and Pacchiarotti 2012, 549-582. For the *cella civiciana* in Rome, cf. Chioffi 1993; Gatti 1934; Mancini 1913. For port and *dolia defossa* of Marseille, cf. Hesnard 2004, 175-204; 1995, 65-77; 1994, 195-217; France and Hesnard 1995, 78-93; Philippon and Védine 2009, 40-46. For dolia defossa along the Rhône in southern Gaul, see Carrato 2017, 177-218, 277-590. For Lyon as a point where dolium ships transferred wine to dolia in warehouses to be transferred later to barrels or amphorae, see Tchernia 1997, 121-129; 2016, 108ff.

410 This would support interpretations by Marzano 2013 and De Sena 2005 on the low numbers of amphorae and the reorganization of Italian villa economies during the imperial period. It would also fit with patterns of dolium installations in southern Gaul, many of which were along a river and in an area where *utricularii* (probably wine skin carriers, see **Chapter 2**; Kneissl 1981; Deman 2002) worked.

the mid first century BCE. Its hilltop position, low population, and differentiated storage practice probably explains both the low number of dolia found throughout the settlement and the regular reuse of discarded ceramic objects. The few dolia at the settlement of Cosa were probably utilized for the storage of wine in residences, shops, and the town's warehouse on an intermittent basis; bulk storage of wine and other liquids took place in the hinterland, while liquid storage in the town was separate from its hinterland and was more individualized. Since Cosa did not have agricultural production within the town walls, wine was brought (presumably in skin containers) from the countryside where viticulture was a thriving activity during the last two centuries BCE. But the population of Cosa was too low to require and justify the bulk storage of wine and the coordination and work that came along with it. After the dolia were discarded, reused, or simply fell out of use by the mid first century BCE, almost no dolia were reintroduced to the town again. Instead, the town residents likely stored their wine in small jars or amphorae after the disappearance of dolia.

In the first century CE, there was a large number of dolia and other ceramic storage containers throughout the town of Pompeii, a port town in an important wine-producing region. These vessels were employed at various properties throughout the town (and probably owned by different people) for different functions. Wine fermentation dolia were found in a few production facilities that were on the outskirts of or just outside the town; the dolia and other viticulture equipment helped demarcate the area as a green zone of production, while blending with elements of the hospitality industry. After fermentation, vintners had a range of choices for the storage and packaging containers, which included amphorae, skin containers, and smaller reused ceramic containers.[411] Merchants often used medium-sized dolia in their shops for the bulk storage of wine, the vessel size likely representing a calibration of how much wine customers could consume in a timely manner. The dolia and storage containers were important equipment and architectural elements of Pompeii that enabled the town to be not only a producer of wine, but also a distributor, consumer, and commercial space for wine, grain, and other dry goods throughout the settlement.

The storage practices of Ostia, a major port town/city that served as transshipment point for Rome, are anomalous compared to other settlements. The c. 200 *dolia defossa* of Ostia were concentrated in at least four purpose-built storerooms. The Ostian dolia are among the largest terrestrial dolia, but were not there for the production or fermentation of wine. Instead, they stored wine produced elsewhere. The dolia stored agricultural products for the residents of Ostia and/or Rome; since Ostia was developed and densely populated, these vessels formed an effective storage system for the city, maximizing the storage capacity of precious, limited space. Such an extensive storage regime required sophisticated coordination and huge inputs of labor, but this system was vital for feeding the population. The city's dolia were placed under a regular and reliable workforce, concentrated in a few storehouses where routine maintenance and labor could be centralized.

In sum, dolia were originally viticultural equipment for production facilities in the countryside, and their widespread appearance from the second century BCE onwards acts as a

[411] De Sena and Ikäheimo 2003 posit that the low number of amphorae in Pompeii is because local wine was distributed in skin and/or reused ceramic containers.

valuable, yet hitherto overlooked, index of economic performance; i.e. greater numbers of larger dolia indicated more wine produced and an increased scale of the wine industry. But dolia were more than just markers of how much and rapidly the Roman wine industry was expanding. They contributed to the growing economy by providing farmers the means to produce large quantities of wine. Agricultural sites could now produce much more wine than for just household consumption, even for export overseas. Furthermore, dolia's utility as bulk storage containers extended beyond the context of production as they became important bulk storage vessels for densely populated urban areas. Their growing numbers in towns and cities were the pillars of large urban populations and an urban diet. We have to remember that dolia and other ceramic storage containers in Pompeii and Ostia not only provided sustenance. They were important equipment of shops and bars, important meeting places that were also able to prepare certain foods that most households could not. Dolia became essential equipment for food storage and supported, and perhaps even encouraged, raising levels of urbanism around the capital.

Chapter 6 Conclusion

The dolium was the largest type of ceramic container in the Mediterranean and was the most important element of hardware of the wine industry during the Roman period. When exactly the dolium, as we know it, first appeared on the scene in west-central Italy is murky. By the late third century BCE, dolia were produced in ceramic workshops and, certainly by the second century BCE, they were installed in large numbers in elite Roman villas practicing viticulture, around the same time amphorae exporting wine (Dressel 1, and later Dressel 2-4) were found throughout the Mediterranean. Dolia were used for the fermentation of wine and the storage of both wine and oil, whether long-term at the production site or short-term, such as for sales or the temporary holding between sales or transport. The dolium's complicated, difficult, expensive, and time-consuming production and repair spurred innovations within the industry that drew together the ceramic and architectural industries. This confluence of production, the scale of which seems unparalleled in the ancient world, not only diversified the workshops' output and the workshop owners' economic portfolio, it also married the ceramic and architectural industries. Folding dolium production into *opus doliare* workshops enabled the stable, but not lucrative, branch of brick and tile production to offset and balance the risky, but highly profitable, dolium production. Cushioned by the stability of *opus doliare* workshops, then, dolium makers had more access to resources, equipment, space, and a large community of (craft) knowledge to produce larger, better-made dolia. The result was that the vessel made a major impact wherever and however it was used, from wine production to bulk storage to distribution, feeding into the growing food supply system. A single farm site or villa could now produce hundreds of thousands of liters of wine, while a town had the infrastructure to store wine more efficiently for its residents.[412] But to design, develop, and refine this product required particular conditions and skills, and was an ongoing process that lasted for centuries.

With the rise of an economically and politically unified Mediterranean, the wine trade, and hence the dolium industry, changed and expanded significantly in the Roman Italian peninsula. During the early phases of dolium production, dolia were often made in pottery workshops, some of which were in rural areas. During the first century BCE into the first two centuries CE, dolium production became an increasingly specialized craft that was enabled by imperial markets. As a far-reaching wine industry and large-scale architectural industry grew, so did the supply and demand for wine, bricks, tiles, and dolia. In the area of the urbs, the production of dolia was taken up as a side line by brick manufactories, with this activity involving specialized dolium makers. It is likely that, in some cases, some of these specialists were potters who formerly made dolia in pottery workshops, while some dolium potters might have been slaves trained in *opus doliare* workshops. Dolium production offered high profits, so dolium makers, often in *opus doliare* workshops, manufactured larger, standardized, and more robust dolia. To be able to produce and move such large amounts of wine required vast resources, and craftsmen who made these vessels had to refine their techniques and procedures in order to produce and repair these expensive investments effectively. Dolium

[412] The Villa Pisanella in Boscoreale had over eighty dolia and several presses was estimated to have produced 93,800 liters of wine; Carandini 1985: the Villa Settefinestre near Cosa was estimated to have produced over 100,000 liters of wine on an annual basis.

stamps from Ostia suggest that, by the second century CE, a sizeable group of dolium makers were no longer working independently, but as part of *opus doliare* workshops. Dolium production near areas of high demand, namely the capital, was probably too risky for small workshops and for independent, specialized potters, perhaps due to both issues of risk and advantages from economies of scale. With the emergence of large *opus doliare* workshops, brick and tile production stabilized the investment in dolium manufacture, but the stability and potential lucrative nature of dolium manufacture pulled in specialized dolium makers, many of whom were subservient to the *officinatores* and *domini* of workshops, who benefitted enormously in various ways, including monetary and social.

Fig. 6.1. Sampling and sale of wine from the *cella vinaria*. In the center, workers ladle out wine into an amphora. Stone relief from Ince Blundell Hall, Liverpool World Museum.

As a result, dolia became the keystone storage container of a labor-intensive packaging system that relied on cheap and abundant labor in order to transfer foods from container to container (**Fig. 6.1**). But the advantage was great. The installation of storage hardware vastly allowed an increased scale of production and trade and connected various urban settlements, allowing them to partake in a new scale and form of trade. This crystallizes most clearly at port sites, through which agricultural goods and other commodities were regularly moved in massive quantities. Numerous urban storehouses containing dolia were installed around the same time specialized dolium ships were delivering wine in bulk, perhaps in an attempt to simplify and expedite the cumbersome packaging system that had been in place for a few centuries. In large cities, such as Ostia and Rome, dolia were installed in storerooms that certainly supported the dense *insula* residential units and apartments that did not have individual storage spaces. Moreover, though dolia were designed with the primary purpose to ferment and store wine, they became important multifunctional vessels that were incorporated into not only various storehouses, but also towns and cities, especially retail spaces so distinctive of urban settlements. If the Vesuvian towns can shed light on wider urban food distribution and retail patterns of the Roman Empire during the first century CE, we can infer that dolia and other large-scale ceramic storage vessels became integral components of these spaces, storing perishable foods that would later be prepared in ways that contributed to a particular urban food culture. Dolia in urban settlements fostered an unprecedented level of large-scale storage of foods, feeding into a sophisticated apparatus that signaled and allowed rising levels of urban services and quality of life, and perhaps urbanism more broadly.[413]

Fig. 6.2. Discus from ceramic lamp with relief scene of Diogenes in a dolium, DIOGENE written above the scene. British Museum, inv. No. 1814,0704.174. Image courtesy of the Trustees of the British Museum.

But if we take a step back, and consider the dolium in context, it becomes obvious how extraordinary the whole industry was: over the course of over four hundred years, dolium makers designed and developed, out of raw material typically used for the manufacture of small items, a vessel that was so big that a person could live in it (**Fig. 6.2**).[414] To do so, the dolium industry brought together different industries, workforces, craft skills, knowledge networks, and specialists in a specialized world to spark innovation. As the storage regime for Rome became more sophisticated, the very practices and technologies of storage themselves cast a wider net that drew in more potters, metallurgists, tinkers, architectural workers, laborers, farmers, porters, and migrant and seasonal workers to propel the largest pre-modern wine industry.

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413 For discussion of retail spaces and their role in the urban economy, cf. Ellis 2018.

414 Juvenal *Sat.* 14.306-310: Diogenes supposedly lived in a dolium that was patched up with lead. This motif, appearing on ceramic lamps and sculptural relief, was probably popular in antiquity.

But this system for urban liquid bulk storage was not sustainable in the long-term. The container system revolving around the dolium was large and complex, requiring huge inputs of labor and mass coordination for the upkeep of the hardware and to transfer the foodstuffs between containers and between settlements. This was prohibitively expensive and challenging for some places. Less than a century after their installation, the dolia in Ostia fell out of use. From around the third century, the gradual depopulation of Ostia probably led to decreases in both the need for such a demanding system as well as the labor and resources to keep it in operation. The role of Ostia, and other settlements, in the food supply system also might have been changing, no longer requiring the elaborate packaging system that had been in place.[415] There are many questions and issues that loom beyond the scope of this study, but the decline of dolia left a vacuum that was ultimately filled by a different type of container that eventually dominated Mediterranean trade until the Industrial Revolution: the wooden barrel.

Fig. 6.3. Wooden barrel with name (IANVARIVS) scratched onto stave from along Antonine Wall at Bar Hill Roman Fort, Strathclyde, Scotland, 142-180 CE. Hunterian Museum, GLAHM F.1936.99.

Although the barrel (*cupa* in Latin), a hollow cylindrical bulk container constructed from wooden staves and bound with hoops, gained traction in Italy probably sometime after the third or fourth century CE, it slowly began to enter the scene a few centuries before, bringing major changes to not only the container industries, but to the organization of labor

[415] This demise seems to be empire-wide for the retail industry, cf. Ellis 2018.

(**Fig. 6.3**).[416] Originating in temperate areas in Europe, they were initially used for the fermentation, storage, and transportation of beer, but were then used for large-scale shipments of low-quality wine to supply the Roman troops.[417] Because of the materials and expertise required, barrels were not commonly used in the Mediterranean prior to the third or fourth century.[418] There were only a few places with straight grained wood that was of the right quality for barrels. Furthermore, unlike ceramics, both barrel production and repair were specialized activities, requiring years of experience. According to analogs with barrel production and maintenance in early modern and modern periods, barrels were individually crafted according to its own specifications, and their specialized repair also had to have been done by coopers. Only people trained as barrel makers could fix leaky barrels and replace deteriorating or defective parts. Moreover, the organization of barrel production did not readily map onto the set-up of industries in Roman Italy. Unlike ceramic and terracotta manufacture, barrel production was a specialized activity that could not be incorporated into a large multi-product workshop or done at any stage by non-specialists.

Fig. 6.4. Gravestone, known as the Neumagener Weinschiffs, depicting boat carrying rowers and wine merchants with their wine barrels, dated to 220 CE. Rheinisches Landesmuseum Trier. Wikimedia Commons.

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416 One difficulty in utilizing the textual sources is that the term *cupa* also signified open vats, also made of timber, that were regarded as cellar equipment; this discussion will address only *cupae* used as barrels.

417 Due to their perishable material, barrels are mostly archaeologically invisible. Besides several rare examples of barrels found in anaerobic environments or reused as well linings, barrels were frequently dismantled to reuse their materials. Most of what we know about barrels comes from iconographic representations on stone reliefs. Marlière 2002 provides the most comprehensive catalog of preserved barrels from the Roman period. None are from Italy; most are from Britain, Gaul, Germany, or along the Danube. Barrels are inherently leaky vessels too; since wine evaporated from the vessels, barrels usually contained low-quality wine.

418 Work 2014; Kilby 1971; Ross 1985. Barrels are not mentioned as shipping containers in textual sources until Pliny's time (*NH* 14.27), and may support the notion that barrels began to be adopted in Italy around that period. Later textual sources suggest that barrels became the dominant bulk container for wine storage, and even for its fermentation. Moreover, wine in barrels evaporated at a higher rate and tasted differently from wine in dolia (Pliny *NH* 14.27), which might also be why they were not readily adopted in the Mediterranean.

Fig. 6.5. Stone relief depicting oxen drawing cart with wine barrel. Augsburg Roman Museum.

Although barrels were costly and required regular maintenance and repair, they offered significant benefits for large-scale transport: large capacities, efficiency, and portability. They were more efficient than ceramic containers, that is they could hold more liters of content per kilogram of container weight, and could often be much larger, with capacities of 500 to 1,000 liters. They could easily be transported on both ships and carts and they could be rolled and stacked (**Figs. 6.4-5**). If the wooden staves were labeled, barrels could be disassembled and reassembled, and could therefore be easily transported with return cargoes. Barrels and casks could also bounce when dropped, so although barrels could be leaky from damage, they did not easily shatter as would an amphora. Furthermore, people did not have to transfer wine from barrels to other containers, as was the case with wine stored in ceramic containers. But it was their manner of use that most radically changed the industries and organization of labor that had been in place for centuries. Barrels could, in principle, function as the sole container for fermentation, for storage, and for distribution, so that must and wine remained in barrels throughout every stage, from processing, fermentation, storage, distribution, and consumption (**Fig. 6.6**).

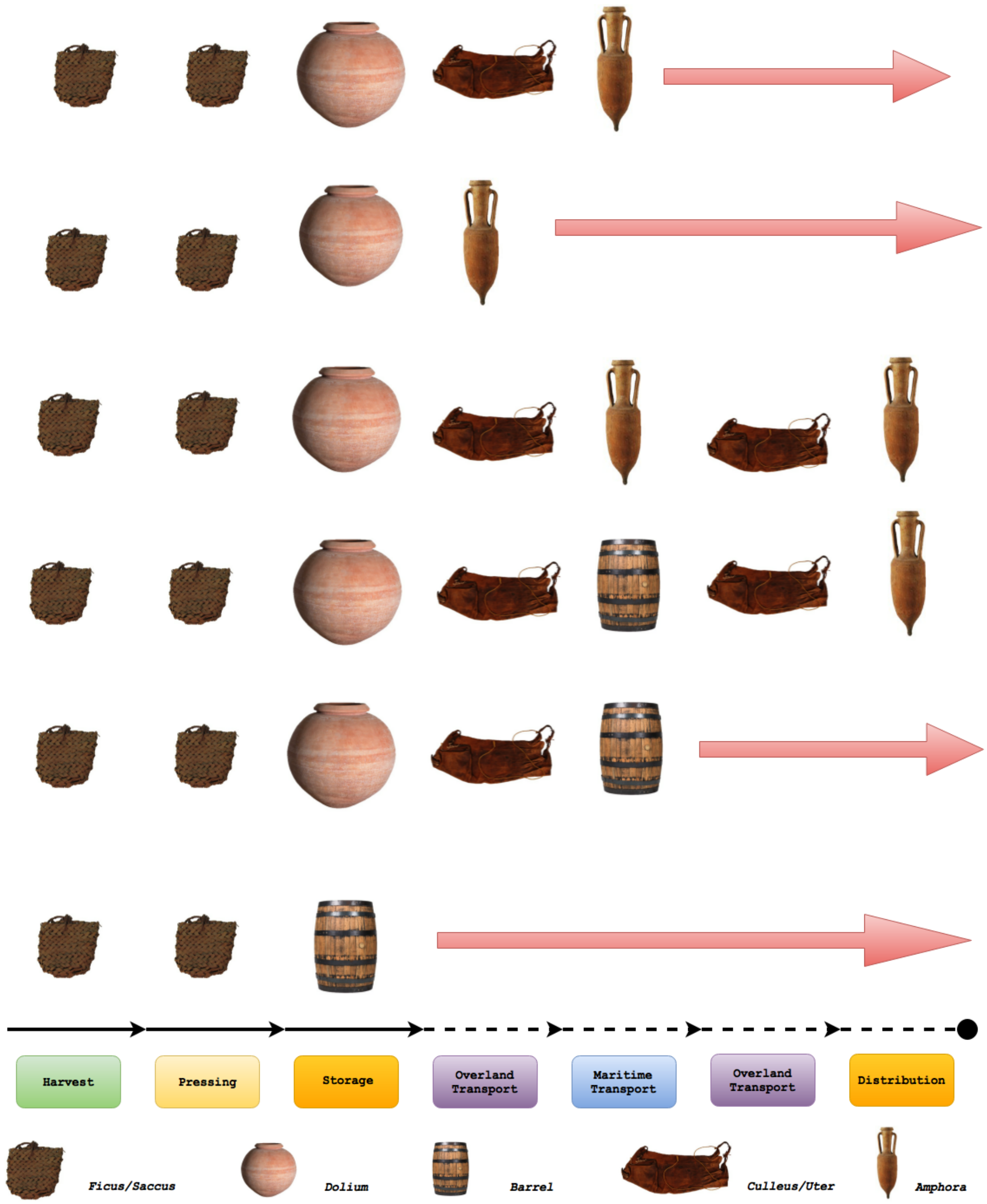


Fig. 6.6. Different possible schemas for the various containers used for the various stages in harvesting, processing, storing, and packaging wine. Barrels could grossly simplify the packaging system by functioning as the sole container for storage, both overland and overseas transport, and distribution.

This new packaging system revolving around the barrel eliminated the labor and coordination for the tedious transferring process between containers, and surely diminished the amount of product lost in the transferring process; transferring the product between containers not only required time and effort, but also probably resulted in some amount of wastage, as liquid was spilled, absorbed into vessel walls, lost due to breakage or inadequate sealing of the receiving vessel, pilfering, and so forth. Barrels greatly outperformed and eventually displaced both amphorae and dolia, and functioned as a pre-industrial bulk storage container, a sort of precursor to steel shipping containers today. With this shift from amphorae and dolia to barrels came new industries, arrangements of labor, and even values.[419] But that is another story.

[419] For instance, Ulpian *Digest* 33.6.3 discusses whether containers are owed with wine that is purchased. Amphorae are understood to be, while dolia are not. The status of cupae, however, depended on whether they were fixed or not. Barrels were considered necessary accessories of wine unless they were fixed, similar to *dolia defossa*.

Bibliography

Adam, J.P. 2005. *Roman building: materials and techniques*. London and New York.

Albert, K. 2012. "Ceramic rivet repair: history, technology, and conservation approaches." *Studies in conservation* 57, sup1: S1-S8.

Alcock, S.E., Cherry, J.F., and J.L. Davis. 1994. "Intensive Survey, Agricultural Practice, and the Classical Landscape of Greece," in *Classical Greece: Ancient Histories and Modern Archaeologies*, edited by. I. Morris, 135-168. Cambridge University Press.

Appadurai, A., ed. 1986. *The social life of things: commodities in cultural perspective.* Cambridge.

Arce, J. and B. Goffaux, eds. 2011. Horrea *d'Hispanie et de la Méditerranée romaine*. Casa de Velázquez.

Bace, E.J. 1984. "Cosa: inscriptions on stone and brick-stamps." PhD dissertation, University of Michigan.

Bagnall, R.S. 2009. "Practical help: chronology, geography, measures, currency, names, prosopography, and technical vocabulary." In *The Oxford handbook of papyrology,* edited by R.S. Bagnall, 179-196. Oxford University Press.

Bagnall, R.S. and B.W. Frier. 1994. *The demography of Roman Egypt*. Cambridge University Press.

Barisashvili, G. 2011. *Making wine in qvevri – a unique Georgian tradition*. Tbilisi.

Barret, J.C. and P. Halstead, eds. 2004. *The Emergence of Civilisation Revisited.* Oxbow Books.

Bentz, M. and U. Kästner, eds. 2006. *Konservieren oder restaurieren: die Restaurierung griechischer Vasen von der Antike bis heute*. Beihefte zum Corpus vasorum antiquorum: 3. Munich.

Bernal-Casasola, D. 2015. "What contents do we characterise in Roman amphorae? Methodological and archaeological thoughts on a 'trending topic'." In *Archaeoanalytics. Chromatography and DNA analysis in archaeology*, edited by C. Oliveira, R.M. Lopes de Sousa Morais, and Á. Morillo Cerdán, 61-83. Esposende.

Bergamini, M, ed. 2007. *Scoppieto 1. Il territorio e i materiali.* Florence.

Bevan, A. 2014. "Mediterranean Containerization." *Current Anthropology* 55(4): 387-418.

Bianchi, E. "L'industria del laterizio e i bolli doliari a Roma in età imperiale." In *Made in Roma: marchi di produzione e di possesso nella società antica*, edited by L. Ungaro, M. Milella, and S. Pastore, 28-30. Rome: Gangemi Editore spa.

Bilde, P.G. and S. Handberg. 2012. "Ancient repairs on pottery from Olbia Pontica." *Americal Journal of Archaeology* 116.3: 461-481.

Bintliff, J. 1997. "Regional Survey, Demography, and the Rise of Complex Societies in the Ancient Aegean: Core-Periphery, Neo-Malthusian, and Other Interpretive Models." *Journal of Field Archaeology* 24: 1-38.

Blitzer, H. 1990. " ΚΟΡΩ ΝΕΪΚΑ: Storage Jar Production and Trade in the Traditional Aegean." *Hesperia* 59 (4): 675-711.

Bloch, H. 1948. *The Roman brick stamps not published in volume XV 1 of the "Corpus inscriptionum Latinarum.* Harvard Studies in Classical Philology.

Bodel, J. 1981. *Roman brick stamps in the Kelsey Museum*. Ann Arbor.
Bond, S.E. 2016. *Trade and taboo: disreputable professions in the Roman Mediterranean*. Ann Arbor.
Bonifay, M. 2004. *Etudes sur la céramique romaine tardive d'Afrique*. Oxford.
Bonifay, M. and J.-C. Tréglia, eds. 2007. *LRCW 2. Late Roman coarse wares, cooking wares and amphorae in the Mediterranean : archaeology and archaeometry*. Oxford.
Borowski, O. 1998. *Every Living Thing: Daily Use of Animals in Ancient Israel.* Walnut Creek.
Bos, J.E.M.F. 2007. "Jar stoppers, seals, and lids, 1999 season." In *Berenike 1999/2000: Report of the Excavations at Berenike, including excavations in Wadi Kalalat and Siket, and the survey of the Mons Smaragdus Region*, edited by S.E. Sidebotham and W.Z. Wendrich, 258-269. Los Angeles.
Bos, J.E.M.F. 2000. "Jar stoppers and seals." In *Berenike 1998: Report of the 1998 Excavations at Berenike and the survey of the Eastern Desert, including excavations in Wadi Kalalat*, edited by S.E. Sidebotham and W.Z. Wendrich, 275-303. Leiden.
Bos, J.E.M.F. and C. Helms 2000. "Jar stoppers and seals." In *Report of the 1998 excavations at Berenike and the survey of the Egyptian Eastern Desert, including the excavations in Wadi Kalalat*, edited by S.E. Sidebotham and W.Z. Wendrich, 275-303. Leiden.
Bowman, A. and A. Wilson, eds. 2009. *Quantifying the Roman Economy: methods and problems.* University of Oxford Press.
Bowman, A. and A. Wilson, eds. 2013. *The Roman agricultural economy : organization, investment, and production*. Oxford University Press.
Bragatini, I., de Vos, M., and F.P. Badoni. 1981. *Pitture e pavimenti di Pompei. Regioni I, II, III.* Rome.
Brenni, G.M.R. 1985. "The dolia and the sea-borne commerce of imperial Rome." MA thesis, Texas A&M University.
Breton, E. 1870. *Pompéi décrite et dessinée suivie d'une notice sur Herculaneum.* Paris.
Brown, F.E. 1951. *Cosa I: History and Topography*. Memoirs of the American Academy in Rome, Vol. 20.
Brown, F.E. 1980. *Cosa. The Makings of a Roman Town.* University of Michigan Press.
Brown, F. 1984. "The northwest gate of Cosa and its environs (1972-1976)." In .. 493-498.
Brown, F., Richardson, E.H. and L. Richardson. 1993. *Cosa III. The buildings of the forum: colony, municipium, and village*. *Memoirs of the American Academy in Rome* 37. University Park, PA.
Brun, J.-P., Cullin-Mingaud, M., Figueiral, I., Monteix, N., Pernot M., Chiaretti B., and V. Monaco. 2005. "Pompéi, Herculanum (Naples) et Saepinum (Molise) : recherches sur l'artisanat antique. *Mélanges de l'École française de Rome. Antiquité*, 117.5: 317-339.
Bruno, V.J. and R.T. Scott. 1993. *Cosa IV: the houses*. Memoirs of the American Academy in Rome. Ann Arbor: University of Michigan Press.
Bruun, C., ed. 2005. *Interpretare i Bolli Laterizi di Roma e della Valle del Tevere.* Institutum Romanum Finlandiae.
Camodeca, G. 1999. *Tabulae Pompeianae Sulpiciorum (TPSulp.): Edizione Critica dell'archivio putelolano deii Suplicii.* Vetera.

Carafa, P. and P. Pacchiarotti. 2012. "Regione XVI. Transtiberim." In *Atlante di Roma antica: Biografia e ritratti della città, 1. Testi e immagini*, edited by A. Carandini, 549-582. Rome.

Carandini, A., ed. *Setttefinestre: una villa schiavistica nell'Etruria romana.* 3 vols. Modena.

Carandini, A. and F. Cambi, eds. 2002. *Paesaggi d'Etruria: Valle dell'Albegna, Valle d'Oro, Valle del Chiarone, Valle del Tafone : progetto di ricerca italo-britannico seguito allo scavo di Settefinestre.* Rome.

Carcopino, J. 1909. "Ostiensia – I. Glanures épigraphiques." *Mélanges d'archéologie et d'histoire* 29: 341-364.

Carrato, C. 2017. *Le* dolium *en Gaule Narbonnaise (I^er^ a.C.-III^e^ S. p.C). Contribution à l'histoire socio-économique de la Méditerranée nord-occidentale.* Mémoires 46, Ausonius Edition. Bordeau.

Casson, L. 1971. *Ships and seamanship in the ancient world.* Johns Hopkins University Press.

Castagnoli, F. 1980. "Installazioni portuali a Roma." *MAAR* 36: 35–42.

Ceci, M. 2001. "La production des lampes a huile: l'exemple de l'atelier d'Annius Serapiodorus." *Descoeudres J.-P. 2001*: 192-195.

Ceci, M. 2003. "L'officina di Annius Serapiodorus ad Ostia." *ReiCretActa* 38: 73-76.

Cheung, C. and G. Tibbott, G. forthcoming. "The Dolia of Regio I, Insula 22: Evidence for the Production and Repair of Dolia." In *Fecisti Cretaria. Produzione e Circolazione Ceramica a Pompei: Stato degli Studi e Prospettive di Ricerca, Atti del Convegno,* edited by M. Osanna and L. Toniolo. Roma.

Chioffi, L. 1993. "Cella Civiciana." In *Lexicon Topographicum Urbis Romae I (A–C)*, edited by E.M. Steinby, 256. Rome.

Christakis, K.S. 2005. *Cretan Bronze Age Pithoi: Traditions and Trends in the Production and Consumption of Storage Containers in Bronze Age Crete.* INSTAP Academic Press.

Christakis, K.S. 2008. *The politics of storage: storage and sociopolitical complexity in neopalatial Crete.* Philadelphia: INSTAP Academic Press.

Churchill, J. 1983. *The complete book of tanning skins and furs.* Mechanicsburg.

Claridge, A. 1990. "Ancient techniques of making joins in marble statuary." In *Marble: art historical and scientific perspectives on ancient sculpture*, edited by M. True and J. Podany, 135-162. Malibu.

Cole, K. and M. Kirwan, eds. 2011. *Food and beverage packaging technology*. Second Edition. Oxford.

Comodi, P, Nazzareni, S. and D. Perugini. 2007. "Dolia e mortaria: analisi archeometriche." In *Scoppieto 1. Il territorio e i materiali*, edited by M. Bergamini, 187-198. Florence.

Cooper, F.A. 2008. "Greek engineering and construction." In *The Oxford Handbook of engineering and technology in the classical world*, edited by J.P. Oleson, 225-255. New York.

Costin, C. 1991. 'Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production,' in *Archaeological Method and Theory*, edited by M. Schiffer, 1-56. Tucson.

Coulston, J. and H. Dodge, eds. 2000. *Ancient Rome: the archaeology of the ancient city.* Oxford.

Creese, J.L. 2012. "Social contexts of learning and individual motor performance." In *Archaeology and apprenticeship: body knowledge, identity, and communities of practice*, edited by W. Wendrich, 43-60. Tucson: University of Arizona Press.
Curtis, R.I. 2015. "Storage and Transport," in *A Companion to Food in the Ancient World,* edited by J. Wilkins and R. Nadeau, 173-182. John Wiley & Sons Inc.
Curtis, R.I. 2001. *Ancient Food Technology*. Leiden, Boston, and Köln.
Csikszentmihalyi, M. 1996. *Flow and the psychology of discovery and invention*. New York.
Dalby, A. 1998. *Cato. On Farming. De Agri Cultura: a modern translation with commentary*. Blackawton, Devon.
D'Altroy, T.N., and T.K. Earle. 1985. "Staple Finance, Wealth Finance, and Storage in the Inka Political Economy." *Current Anthropology*, vol. 26(2): 187-206.
Davis, J.R. 2000. *Corrosion. Understanding the basics*. The Materials Information Society. ASM Materials.
Davoli, P. 2005. *Oggetti in argilla dall'area templare di Bakchias (El-Fayyum, Egitto): catalogo dei rinvenimenti delle campagne di scavo 1996- 2002*. Pisa.
De Caro, S. 1994. *La villa rustica in località Villa Regina a Boscoreale*. Pubblicazioni scientifiche del Centro di studi della Magna Grecia dell'Università degli Studi di Napoli Federico II. Rome: L'Erma di Bretschneider.
DeLaine, J. 1997. *The baths of Caracalla: a study in the design, construction, and economics of large-scale building projects in imperial Rome*. Portsmouth, RI: Journal of Roman Archaeology Supplement Series.
DeLaine, J. 2004. "Designing for a market: '*medianum*' apartments at Ostia. *JRA* 17: 146-176.
DeLaine, J. 2005. "The commercial landscape of Ostia." In *Roman working lives and urban living*, edited by A. MacMahon and J. Price, 29-47. Oxford.
DeLaine, J. 2010. "Structural experimentation: the lintel arch, corbel and tie in western Roman architecture." *World Archaeology* 21.3: 407-424.
Della Corte, M. 1965. *Case e abitanti di Pompei*. Naples.
Deman, A. 2002. "Avec les utriculaires sur les sentiers muletiers de la Gaule romaine." *Cahiers du Centre Gustave Glotz*. 13.1: 233-246.
Demesticha, S. ed. 2015. *Per terram, per mare: seaborne trade and the distribution of Roman amphorae in the Mediterranean*. Uppsala.
Denecker, E. and K. Vandorpe. 2007. "Sealed Amphora Stoppers and Tradesmen in Greco-Roman Egypt: Archaeological, Papyrological, and Inscriptional Evidence." *BABesch* 82: 115-128.
De Sena, E.C. 2005. "An Assessment of Wine and Oil Production in Rome's Hinterland: Ceramic, Literary, Art Historical and Modern Evidence." In *Roman villas around the Urbs: Interaction with Landscape and Environment. Proceedings of a Conference Held at the Swedish Institute in Rome, September 17–18 2004*, edited by B. Santillo Frizell and A. Klynne, 135-49. Rome.

De Sena, E.C. and J.P. Ikäheimo. 2003. "The supply of amphora-borne commodities and domestic pottery in Pompeii 150 BC–AD 79: Preliminary evidence from the House of the Vestals." *European Journal of Archaeology* 6.3: 301-321.

De Simone, G.F. 2017. "The agricultural economy of Pompeii: surplus and dependence." In *The Economy of Pompeii*, edited by M. Flohr and A. Wilson, 23-52. Oxford.

De Spagnolis, M.C. 2002. *La villa "N. Popidi Narcissi Maioris": in Scafati suburbio orientale di Pompei.* Rome.

Dicus, K. 2014. "Resurrecting refuse at Pompeii: the use-value of urban refuse and its implications for interpreting archaeological assemblages." In *TRAC 2013: proceedings of the twenty third theoretical Roman Archaeology Conference,* 56-69. Oxford

Dietler, M. 2010. "Consumption." In *The Oxford Handbook of Material Culture Studies*, edited by D. Hicks and M.C. Beaudry, 209-228. Oxford.

Diggory, E. 2018, February 2 . "Why Georgian qvevri are so efficient at making natural wine." Accessed April 17, 2018, from http://www.the-buyer.net/insight/buyer-road-unique-qvevri-georgia/.

Dinsmoor, W.B. 1922. "Structural iron in Greek architecture." *American Journal of Archaeology* 26.2: 148-158.

Dinsmoor, W.B. 1933. "The temple of Apollo at Bassae." *Metropolitan Museum Studies* 4.2: 204-227.

Dobres, M.-A. 1999. "Technology's Links and Chaînes: The Processual Unfolding of Technique and Technician," in *The Social Dynamics of Technology: Practice, Politics, and World Views*, edited by M.-A. Dobres and C. Hoffman, 124-146. Smithsonian.

Dobres, M.-A and C. Hoffman, eds. 1999. *The Social Dynamics of Technology: Practice, Politics, and World Views*. Smithsonian Institution Press.

Dooijes, R. and O.P. Nieuwenhuyse. 2006. "Ancient repairs: techniques and social meaning." In *Konservieren oder restaurieren: die Restaurierung griechischer Vasen von der Antike bis heute*, edited by M. Bentz and U. Kästner, 15-20. Beihefte zum Corpus vasorum antiquorum: 3. Munich.

Duncan-Jones, R.P. 1974. *The economy of the Roman empire. Quantitative studies.* Cambridge.

Duncan-Jones, R.P. 1976a. "The choenix, the artaba, and the modius." *ZPE* 21: 43-52.

Duncan-Jones, R.P. 1976b. "The size of the modius castrensis." *ZPE* 21: 53-62.

Dyson, S.L. 1976. *Cosa: The Utilitarian Pottery*. Memoirs of the American Academy in Rome.

Earle, T.K. 2002. "Political Economies of Chiefdoms and Agrarian States," in *Bronze Age Economics: The Beginnings of Political Economies*, edited by T.K. Earle, 1-18. Westview Press.

Elia, O. 1975. "La scultura pompeiana in tufo." *Cronache Pompeiane* 1: 118-143.

Ellis, S. J. 2004. "The distribution of bars at Pompeii: archaeological, spatial and viewshed analyses." *Journal of Roman Archaeology* 17: 371-384.

Ellis, S.J. 2018. *The Roman retail revolution. The socio-economic world of the* taberna. Oxford University Press.

Emblem, A. and H. Emblem. 2012. *Packaging technology. Fundamentals, materials, and processes.* Woodhead publishing.
Erdkamp, P. 1998. *Hunger and the Sword. Warfare and Food Supply in Roman Republican Wars (264-30 BC).* Cambridge.
Erdkamp, P. 1999. "Agriculture, underemployment, and the cost of rural labour in the Roman world." *Classical Quarterly* 49: 556-572.
Erdkamp, P. 2001. "Beyond the limits of the 'consumer city.' A model of the urban and rural economy in the Roman world." *Historia: Zeitschrift für Alte Geschichte* 50.3: 332-356.
Edrkamp, P. 2005. *The Grain Market in the Roman Empire: A Social, Political. and Economic Study.* Cambridge University Press.
Erdkamp, P., ed. 2013. *The Cambridge companion to ancient Rome.* Cambridge University Press.
Escalera, A.V., Bianchi, G. and J.A. Quiros, eds. 2013. *Horrea, barns and silos. Storage and incomes in Early Medieval Europe.* Agritalpen Zerbitzua.
Fentress, E., ed. 2003. *Cosa V. An intermittent town.* Memoirs of the American Academy in Rome. Ann Arbor.
Fentress, E., Goodson, C. and M. Maiuro, eds. 2017. *Villa Magna. An imperial estate and its legacies: excavations 2006-2010.* London.
Fiorelli, G. 1860. *Pompeianarum antiquitatum historia.* Vol. 1. Naples.
Fiorelli, G. 1862. *Pompeianarum antiquitatum historia.* Vol. 2. Naples.
Fiorelli, G. 1864. *Pompeianarum antiquitatum historia.* Vol. 3. Naples.
Fiorelli, G. 1873. *Gli scavi di Pompei dal 1861 al 1872.* Naples.
Fiorelli, G. 1875. *Descrizione di Pompei.* Naples.
Flohr, M. 2013. "Tanning, tanners." In *The Encyclopedia of Ancient History,* edited by R.S. Bagnall, K. Brodersen, C.B. Champion, A. Erskine, and S.R. Huebner, 6526-7. Blackwell.
Forbes, H. and Foxhall, L. 1995. "Ethnoarchaeology and Storage in the Ancient Mediterranean: Beyond Risk and Survival," in J. Wilkins, D. Harvey, and M. Dobson (eds.), *Food in Antiquity*, 69-86. University of Exeter Press.
Foxhall, L. 1990. "The Dependent Tenant: Land Leasing and Labour in Italy and Greece." *Journal of Roman Studies* 80: 97-114.
Foxhall, L. 1993. "Oil Extraction and Processing Equipment in Classical Greece," in *La Production du Vin et de l'Huile en Méditerranée*, edited by M.-C. Amouretti, J.-P. Brun, and D. Eitam,183-200. Athens: École francaise d'Athènes.
Foxhall, L. and H. Forbes. 1982. "Sitometria: The Rôle of Grain as a Staple Food in Classical Antiquity." *Chiron* 12: 41-90.
France, J. and A. Hesnard. 1995. "Une statio du quarantième des Gaules et les opérations commerciales dans le port romain de Marseille (place Jules-Verne)." *JRA* 8: 78-93.
Frazzoni, L. 2016. "Mortaria." In *Made in Roma: marchi di produzione e di possesso nella società antica*, edited by L. Ungaro, M. Milella, and S. Pastore, 25-27. Rome: Gangemi Editore spa.

Frier, B.W. 1983. "Roman Law and the Wine Trade: The Problem of 'Vinegar Sold as Wine,'" in *Zeitschrift der Savigny-Stiftung für Rechtsgeschichte. Romanistische Abteilung*, edited by T. Mayer-Maly, D. Nott, A. Laufs, W. Ogris, M. Heckel, P. Mikat, and K.W. Norr, 257-295. Hermann Böhlaus Nachf.

Furlan, G. 2017. "When absence means things are going well: waste disposal in Roman towns and its impact on the record as observed in Aquileia." *European Journal of Archaeology* 20.2: 317-345.

Gallimore, S. 2010. "Amphora production in the Roman world. A view from the Papyri." *The Bulletin of the American Society of Papyrologists* 47: 155-184.

Ganzert, J. 1996. *Der Mars-Ultor-Tempel auf dem Augustusforum in Rom*. Mainz am Rhine. Garachon, I. 2010. "Old repairs of china and glass." *The Rijksmuseum Bulletin:* 34-55.

Garnsey, P. 1988. *Famine and Food Supply in the Graeco-Roman World.* Cambridge.

Garnsey, P. 1998. *Cities, peasants, and food in classical antiquity : essays in social and economic history*. Cambridge University Press.

Garnsey, P. and Morris, I. 1989. "Risk and the Polis: the Evolution of Institutionalized Responses to Food Supply Problems in the Ancient Greek State," in P. Halstead and J. O'Shea (eds.), *Bad Year Economics Cultural Responses to Risk and Uncertainty*, 98-105. Cambridge.

Gatti, G. 1903. "Ostia - Rinvenimento di dolii frumentarii." *Notizie degli Scavi d'Antichità*: 201-202.

Gatti, G. 1934. "Saepta Iulia e Porticus Aemilia nella forma severiana." *Bulletino Communale* 62: 123-144.

George, R. 2013. *Ninety Percent of Everything: Inside Shipping, the Invisible Industry That Puts Clothes on Your Back, Gas in Your Car, and Food on Your Plate*. Picador.

Giannopoulou, M. 2010. *Pithoi: Technology and History of Storage Vessels through the Ages*. Archaeopress.

Giardino, C. 2012. "Archaeometric analyses of metal, glass, and plaster." In *The chora of Metaponto 4. The late Roman farmhouse at San Biagio*, edited by E. Lapadula, 194-207. Austin.

Gliozzo, E. 2013. "Stamped bricks from the *ager Cosanus* (Orbetello, Grosseto): integrating archaeometry, archaeology, epigraphy, and prosopography." *Journal of Archaeological Science* 40: 1042-1058.

Gliozzo, E., Iacoviello, F. and L.M. Foresi. 2014. "Geosources for ceramic production: the clays from the Neogene-Quaternary Albegna Basin (southern Tuscany)." *Applied Clay Science* 91-92: 105-116.

Goodman, P. 2016. "Working together: clusters of artisans in the Roman city." In *Urban craftsmen and traders in the Roman world*, edited by A. Wilson and M. Flohr, 301-333. Oxford.

Gurt i Esparraguera, J. Ma., Buxeda i Garrigós, J. and M.A. Cau Ontiveros, eds. 2005. *LRCW I : late Roman coarse wares, cooking wares and amphorae in the Mediterranean : archaeology and archaeometry*. Oxford.

Guven, N. 1993. "Molecular aspects of clay-water interactions." In *Clay-water interface and its rheological properties. CMS workshop lectures* 4, edited by N. Guven and R.M. Pollastro, 2-79. Boulder.

Halstead, P. 1987. "Traditional and Ancient Rural Economy in Mediterranean Europe: Plus ça change?" *Journal of Hellenic Studies* 107: 77-87.

Halstead, P. 1989. "The Economy Has a Normal Surplus: Economic Stability and Social Change Among Early Farming Communities of Thessaly, Greece," in P. Halstead and J. O'Shea (eds.), *Bad Year Economics Cultural Responses to Risk and Uncertainty*, 68-80. Cambridge.

Halstead, P. and C. Frederick, eds. 2000. *Landscape and Land Use in Postglacial FGreece*. Sheffield Academic Press.

Halstead, P. and O'Shea, J. 1982. "A Friend in Need is a Friend Indeed: Social Storage and the Origins of Social Ranking," in *Ranking, Resource, and Exchange. Aspects of the Archaeology of Early European Society*, edited by C. Renfrew and S. Shennan, 92-99. Cambridge University Press.

Halstead, P. and O'Shea, J. 1989. "Introduction: Cultural Responses to Risk and Uncertainty," in P. Halstead and J. O'Shea (eds.), *Bad Year Economics Cultural Responses to Risk and Uncertainty*, 1-7. Cambridge

Hamer, F. and J. Hamer. 2004. *The potter's dictionary of materials and techniques*. Philadelphia.

Han, J.H., ed. 2005a. *Innovations in food packaging.*

Han, J.H. 2005b. "New technologies in food packaging: overview." In *Innovations in food packaging*, edited by J.H. Han, 3-11.

Harper, D. 1987. *Working knowledge: skill and community in a small shop*. Chicago.

Hasaki, E. 2012. "Craft apprenticeship in ancient Greece: reaching beyond the masters." In *Archaeology and apprenticeship: body knowledge, identity, and communities of practice*, edited by W. Wendrich, 171-202. Tucson: University of Arizona Press.

Hastorf, C. and L. Foxhall. 2017. "The social and political aspects of food surplus." *World Archaeology* 49.1; 26-39.

Helms, K. 2013. "Guarding Grapes in Roman Egypt (P.Mich. inv. 438)." *BASP* 50: 135-143.

Hermansen, G. 1978. "The Population of Imperial Rome: The Regionaries." *Historia: Zeitschrift für Alte Geschichte* 27.1: 129-168.

Hermansen, G. 1981. *Ostia. Aspects of Roman city life*. University of Alberta Press.

Heslin, K. 2011. "Dolia shipwrecks and the wine trade in the Roman Mediterranean." In *Maritime Archaeology and Ancient Trade in the Mediterranean,* edited by D. Robinson and A. Wilson, 157-168. Oxford Centre for Maritime Archaeology, Institute of Archaeology. Oxford.

Hesnard, A. 1994. "Une nouvelle fouille du port de Marseille, place Jules-Verne." *Comptes rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 138(1): 195-217.

Hesnard, A. 1995. "Les ports antiques de Marseille, Place Jules-Verne 1." *JRA* 8: 65-77.
Hesnard, A. 2004. "Vitruve, *De architectura*, V, 12 et le port romain de Marseille." In *Le strutture dei porti e degli approdi antichi*, edited by A. Gallina Zevi and R. Turchetti, 175-203. Rome.
Hesnard, A. and P. Gianfrotta. 1989. "Les bouchons d'amphore en Pouzzolane." In *Amphores romaines et histoire économique. Dix ans de recherche. Actes du colloque de Sienne (22-24 mai 1986)*, 393-441. Publications de l'École française de Rome, 114. Rome.
Hickey, T.M. 2012. *Wine, wealth, and the state in late antique Egypt*. University of Michigan Press.
Hilgers, W. 1969. *Lateinische Gefässnamen: Bezeichnung, Funktion und Form römischer Gefässe*. Beihefte der BJb 31. Dusseldorf.
Hin, S. 2013. *The Demography of Roman Italy. Population Dynamics in an Ancient Conquest Society 201 BCE–14 CE*. Cambridge University Press.
Hingley, R. 2005. *Globalizing Roman culture: unity, diversity, and empire*. London: Routledge.
Hong, S., Candelone, J.P., Patterson, C.C. and Boutron, C.F., 1994. "Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman civilizations." *Science 265* 5180: 1841-1844.
Hodder, I. 2012. *Entangled: and archaeology of the relationships between humans and things*. Malden, MA: Wiley-Blackwell.
Hopkins, K. 1978. *Conquerors and Slaves*. Cambridge University Press.
Hopkins, K. 1980. "Taxes and Trade in the Roman Empire." *JRS* 70: 101-125.
Horden, P. and Purcell, N. 2000. *The Corrupting Sea*. Wiley-Blackwell.
Howe, T. 2008. *Pastoral Politics: Animals, Agriculture and Society in Ancient Greece*. Regine Books.
Husselman, E.M. 1952. "The granaries of Karanis." *Transactions and Proceedings of the American Philological Association* 83: 56-73.
Ingold, T. 2013. *Making: anthropology, archaeology, art and architecture*. London and New York.
Jashemski, W. 1967a. "A Pompeian vinarius," *CJ* 5.2: 193–204.
Jashemski, W. 1967b. "The caupona of Euxinus at Pompeii." *Archaeology* 20: 36-44.
Jashemski, W. 1968. "Excavations in the 'foro boario' at Pompeii: a preliminary report." *AJA* 72: 69-73.
Jashemski, W. 1973a. "The discovery of a large vineyard at Pompeii: University of Maryland excavations, 1970." *AJA* 77: 27-41.
Jashemski, W. 1973b. "Large vineyard discovered in ancient Pompeii." *Science* 180: 821-830.
Jashemski, W. 1974. "The discovery of a market-garden orchard at Pompeii: the garden of the 'House of the Ship Europa,'" *AJA* 78: 391–404.
Jashemski, W. 1977. "The excavations of a shop-house garden at Pompeii (I.xx.5)." *AJA* 81: 217-227.
Jashemski, W. 1979a. *The gardens of Pompeii, Herculaneum and the villas destroyed by Vesuvius*. New Rochelle: Caratzas Brothers.

Jasehmski, W. 1979b. "The garden of Hercules at Pompeii (II.viii.6): the discovert of a commercial flower garden." *AJA* 83: 403-411.

Jashemski, W. 1993. *The gardens of Pompeii, Herculaneum and the villas destroyed by Vesuvius*. Vol. 2, Appendices. New Rochelle: Caratzas Brothers.

Jongman, W.M. 2007. "The Early Roman Empire: Consumption." In *The Cambridge Economic History of the Graeco-Roman World,* edited by W. Scheidel, I. Morris, and R. Saller, 592-618. Cambridge.

Joshel, S.R. 1992. *Work, identity, and legal status at Rome. A study of the occupational inscriptions*. Norman and London.

Joyce, R.A. 2015a. "Making Things out of Objects that Move." In *Things in Motion,* edited by R.A. Joyce and S.D. Gillespie, 3-19. Santa Fe: School for Advanced Research Press.

Joyce, R.A. and S.D. Gillespie, eds. 2015b. *Things in motion*. Santa Fe: School for advanced research press.

Kang, D.J. 2015. *Life and learning of Korean artists and craftsmen*. New York.

Keay, S.J. 1984. Late Roman amphorae in the Western Mediterranean: a typology and economic study, the Catalan evidence. Oxford.

Keay, S. 2012. "The port system of imperial Rome." In *Rome, Portus, and the Mediterranean,* edited by S. Keay, 33-67. London.

Kehoe, D.P. 1988. *The Economics of Agriculture on Roman Imperial Estates*. Hypomnemata 89, Göttingen: Vandenhoeck und Ruprecht.

Kehoe, D.P. 2007. "The Early Roman Empire: Production." In *The Cambridge Economic History of the Graeco-Roman World*, edited by W. Scheidel, I. Morris, and R. Saller, 543-569. Cambridge.

Keenan, J.G. 2017. "*P.Oxy.* 24.240. A Revised Edition." *BASP* 54: 237-248.

Kelsey, R.J. 1985. *Packaging in today's society*. Third edition. Lancaster.

Kilby, K. 1971. *The cooper and his trade*. London.

Klapste, J. and P. Sommer, eds. 2001. *Processing, Storage, Distribution of Food: Food in the Medieval Rural Environment*. Brepols.

Kloppenborg, J.S. 2006. *The tenants in the vineyard. Ideology, economics, and agrarian conflict in Jewish Palestine*. Mohr Siebeck.

Klose, A. 2015. *The Container Principle. How a box changes the way we think*. Cambridge, MA and London.

Kneissl, P. 1981. "Die utricularii. Ihr Rolle im gallo-römischen Transportwesen und Weinhandel." *BJ* 181: 169-204.

Königlich Preussische Akademie der Wissenshaften zu Berlin. 1893-. *Corpus Inscriptionum Latinarum*.

Koob, S. 1998. "Obsolete fill materials found on ceramics." *Journal of the American Institute for Conservation* 37: 49-67.

Kopytoff, I. 1986. "The Cultural Biography of Things: Commoditization as Process," in *The Social Life of Things: Commodities in Cultural Perspective*, edited by A. Appadurai, 64 – 91. Cambridge.

Korn, P. 2003. *Woodworking basics. Mastering the essentials of craftsmanship. An integrated approach with hand and power tools*. Newtown, CT.

Korn, P. 2013. *Why We Make Things and Why It Matters: The Education of a Craftsman*. Boston.

Lancaster, L. 2004. *Concrete Vaulted Construction in Imperial Rome: Innovations in Context.* Cambridge.

Lancaster, L.C. 2012. "A new vaulting technique for early baths in Sussex: the anatomy of a Romano-British invention." *Journal of Roman Archaeology* 25: 419-440.

Lancaster, L.C. forthcoming. "Armchair Voussoirs and Hollow Voussoirs: An Investigation into the Diffusion of Vaulting Technology for Bath Building in the Western Roman Empire."

Lanciani, R.A. 1880. *Topografia di Roma antica. I comentarii di Frontino intorno le acque e gli aquedotti. silloge epigrafica aquaria. Memoria del socio corrispondente R. Lanciani presentata nella seduta del 18 gennaio 1880.* Rome.

Laurence, R. 1994. *Roman Pompeii: Space and Society*. Routledge.

Lawall, M.L. and J. Lund. 2011. *Pottery in the archaeological record : Greece and beyond: acts of the international colloquium held at the Danish and Canadian Institutes in Athens, June 20-22, 2008*. Aarhus.

Lazzeretti, A. and S. Pallecchi. 2005. "Le *figlinae* "polivalenti": la produzione di *dolia* e di *mortaria* bollati." In *Interpretare I bolli laterizi di Rome r della valle del Tevere: produzione, storia economica e topografia*, edited by C. Bruun, 213-228. Rome.

Lequément, R. 1975. "Étiquettes de plomb sur des amphores d'Afrique." *Mélanges de l'Ecole française de Rome. Italie et Méditerranée* 87:669-680.

Leveau, P. 2004. "La cité romaine d'Arles et le Rhône: La romanisation d'un espace deltaïque." *AJA* 108.3: 349-375.

LeVine, T., ed. 1992. *Inka Storage Systems*. University of Oklahoma Press.

Levinson, M. 2006. *The box. How the shipping container made the world smaller and the world economy bigger.* Princeton.

Liou, B. and A. Tchernia. 1994. "L'interprétation des inscriptions sur les amphores Dressel 20." *Epigrafia della produzione e della distribuzione. Actes de la VII^e^ rencontre franco-italienne sur l'épigraphie du monde romain (Rome, 5-6 juin 1992),* 133-156. Publications de l'École française de Rome 193.1. Rome.

Lo Cascio, E. 1997. "Le procedure di *recensus* dalla tarda repubblica al tardo antico e il calcolo della popolazione di Roma." *Publications de l'École Française de Rome. 230.*1: 3-76.

Lugli, G. 1957. *La tecnica edilizia romana, con particolare riguardo a Roma e Lazio.* Rome.

Luongo, G. et al. 2003. "Impact of the AD 79 explosive eruption on Pompeii, II. Causes of death of the inhabitants inferred by stratigraphic analysis and areal distribution of the human casualties." *Journal of Volcanology and Geothermal Research* 126: 169-200.

MacMahon, A. 2005. "The *taberna* counters of Pompeii and Herculaneum." In *Roman working lives and urban living*, edited by A. MacMahon and J. Price, 70-87. Oxford.

MacMahon, A. and J. Price, eds. *Roman working lives and urban living.* Oxford.

Maiuri, A. 1928. *Pompeii.* Novara.

Maiuri, A. 1956. *Pompei ed Ercolano. Fra case ed abitanti.* Padua.

Manacorda, D. 1978. "The Ager Cosanus and the production of the amphorae of Sestius: new evidence and a reassessment." *The Journal of Roman Studies* 68: 122-131.

Manacorda, D., 1981. "Produzione agricola, produzione ceramica e proprietari nell'-*ager cosanus* nel I a.C." In *Società romana e produzione schiavistica 2. Merci, mercati e scambi nel Mediterraneo*, edited by A. Giardina and A. Schiavone, 3-54. Bari: Laterza.

Manacorda, D. 1993. "Appunti sulla bollatura in età romana." In *The inscribed economy. Production and distribution in the Roman empire in the light of instrumentum domesticum: the proceedings of a conference held at the American Academy in Rome on 10-11 January 1992*, edited by W.V. Harris, 37-54. Ann Arbor.

Manca, R., Pagliantini, L., Pecchioni, E., Santo, A.P., Cambi, F., Chiarantini, L., Corretti, A., Costagliola, P., Orlando, A., and M. Benvenuti. "The island of Elba (Tuscany, Italy) at the crossroads of ancient trade routes: an archaeometric investigation of dolia defossa from the archaeological site of San Giovanni." *Mineralogy and Petrology* 110.6: 693-711.

Mancini, G. 1913. "Roma. Via Labicana." *Notizie degli Scavi d'Antichità*: 69-71, 119, 173, 226.

Marabini Moevs, M.T. 2006. *Cosa: the Italian sigillata.* Memoirs of the American Academy in Rome. Ann Arbor: University of Michigan Press.

Marasco, V. 2014. "A Historical Account of Archaeological Discoveries in the Region of Torre Annunziata," in *Oplontis: Villa A ("of Poppaea") at Torre Annunziata, Italy*, edited by J.R. Clarke and N.K. Muntasser, 209-354. American Council of Learned Societies.

Marlier, S. and Sibella, P. 2008. "La Giraglia, a *dolia* wreck of the 1st century BC from Corsica, France: study of its hull remains." *The International Journal of Nautical Archaeology* 31.2: 161-171.

Marlière, E. 2001. "Le tonneau en Gaule romaine." *Gallia* 58:181–201.

Marlière, E. 2002. *L'outre et le tonneau dans l'Occident romain.* Montagnac: éditions monique mergoil.

Marlière, E. and Torres Costa, J. 2007. "Transport et stockage des denrées dans l'Afrique romaine: le rôle de l'outre et du tonneau." In *In Africa et in Hispania: Études sur l'huile africaine*, edited by A. Mrabet and J. Remesal Rodríguez, 85-106. Barcelona.

Martelli, E. 2013. *Sulle Spalle dei* Saccarii. *Le rappresentazioni di facchini e il trasporto di derrate nel porto di Ostia in epoca imperiale.* BAR International Series 2467. Oxford.

Martin, R. and P. Varène. 1973. *Le monument d'Ucuetis à Alesia. Gallia* supplement 26. Paris.

Marzano, A. 2007. *Roman villas in central Italy. A social and economic history.* Leiden; Boston: Brill.

Marzano, A. 2013. "Agricultural production in the hinterland of Rome: wine and olive oil." In *The Roman agricultural economy : organization, investment, and production*, edited by A. Bowman and A. Wilson, 85-106. Oxford University Press.

Mattingly, D. and G. Aldrete. 2000. "The feeding of imperial Rome: the mechanics of the food supply system," In *Ancient Rome: The Archaeology of the Ancient City*, edited by J. Coulston and H. Dodge, 142-165. Oxford.

Mau, A. 1889. "Scavi di Pompei 1886-88. Insula IX, 7." *Mitteilungen des Deutschen Archäologischen Instituts. Römische Abteiluing* 4: 3-31.

Mayerson, P. 2001. "Jar stoppers and the sealing of wine jars." *ZPE* 136: 217-220.

Mayerson, P. 2000. "The monochron and dichoron: standard measures for wine based on the Oxyrhynchition." *ZPE* 131: 169-172.

Mayerson, P. 1998. "The sack (ϲάκκοϲ) is the artaba writ large." *ZPE* 122: 189-194.

McCallum, M. 2010. "The Supply of Stone to the City of Rome: A Case Study of the Transport of Anician Building Stone and Millstone from the Santa Trinità Quarry (Orvieto)." In *Trade and Exchange: Archaeological Studies from History and Prehistory*, edited by C. White and C. Dillian, 75-94. Springer: New York.

McCallum, M. and J.T. Peña, 2010. "A Reassessment of the Two Potteries at Pompeii: I.20.2-3 and the Via Superiore." *Rei cretariae romanae fautorum acta* 41: 229-238.

McCann, A.M 1987. *The Roman port and fishery of Cosa : a center of ancient trade*. Princeton University Press.

McCormick, M. 2012. "Movements and markets in the first millennium: information, containers and shipwrecks." In *Trade and markets in Byzantium*, edited by C. Morrisson, 51–98. Washington, DC: Dumbarton Oaks Research Library and Collection.

Menchelli, S., Santaro, S., Pasquinucci, M. and G. Guiducci, eds. 2010. *LRCW3. Late Roman coarse wares, cooking wares and amphorae in the Mediterranean : archaeology and archaeometry : comparison between western and eastern Mediterranean*. Oxford.

Meyer, F.G. 1980. "Carbonized food plants of Pompeii, Herculaneum, and the Villa at Torre Annunziata." *Economic Botany* 34.4: 401-437.

Miller, H. M.-L. 2009. *Archaeological Approaches to Technology*. Left Coast Press.

Miller, H. M.-L. 2012. "Types of learning in apprenticeship." In *Archaeology and apprenticeship: body knowledge, identity, and communities of practice*, edited by W. Wendrich, 224-239. Tucson: University of Arizona Press.

Minutoli, D. 2014. "Stampigliature su coperture d'anfora in argilla provenienti da Antinoupolis." *Analecta Papyrologica* 26: 323-358.

Morel, J.-P. 1981. *Céramique campanienne: les formes*. École française de Rome. Rome.

Morley, N. 2002. *Metropolis and Hinterland : the city of Rome and the Italian economy, 200 BC-AD 200*. Cambridge University Press.

Morley, N. 2007. "The Early Roman Empire: Distribution." In *The Cambridge Economic History of the Graeco-Roman World,* edited by W. Scheidel, I. Morris, and R. Saller, 570-591. Cambridge.

Morley, N. 2013. "Population size and social structure." In *The Cambridge companion to ancient Rome*, edited by P. Erdkamp, 29-44. Cambridge University Press.

Mulder, S.F. 2007. "Jar stoppers, seals, and lids, 2000 season." In *Berenike 1999/2000: Report of the Excavations at Berenike, including excavations in Wadi Kalalat and Siket, and the survey of the Mons Smaragdus Region*, edited by S.E. Sidebotham and W.Z. Wendrich, 270-284. Los Angeles.

Murphy, E.A. 2016. "Roman workers and their workplaces: some archaeological thoughts on the organization of workshop labour in ceramic production." In *Work, labour, and professions in the Roman world*, edited by K. Verboven and C. Laes, 133-146. Leiden; Boston: Brill.

Murphy, E.A. 2017. "Rethinking standardisation through late antique Sagalassos ceramic production. Tradition, improvisation and fluidity." In *Materialising Roman histories*, edited by A. Van Oyen and M. Pitts, 101-122. Oxford.

Museo dell'Ara Pacis. 2015. *Nutrire L'Impero. Storie di alimentazione da Roma e Pompei.* L'Erma di Bretschneider.

Nachtergael, G. 2000. "Sceaux et timbres de bois d'Égypte. I. En marge des archives d'Hèroninos: cachets et bouchons d'amphores de Théadelphie." *Chronique d'Egypte* 75: 150-173.

Nachtergael, G. 2001. "Sceaux et timbres de bois d'Égypte. II. Les sceaux de grand format." *Chronique d'Égypte* 76: 231-257.

Nachtergael, G. 2003. "Sceaux et timbres de bois d'Égypte. III. La Collection Froehner (suite et fin)." *Chronique d'Égypte* 78: 277-293.

Nappo, S.C. 1988. "Regio I, insula 20," in *Rivista dei Studi Pompeiani.* 2: 186-192.

Nappo, S.C. 1997. "Urban Transformation at Pompeii in the Late 3rd and Early 2nd c. BC," in *Domestic Space in the Roman World: Pompeii and Beyond, JRA Supplement Series* no. 22, edited by R. Laurence and A. Wallace-Hadrill, 91-120.

Nicoletta, N. 2007. "Dolia e mortaria: studio morfologico e ipotesi funzionali." In *Scoppieto 1. Il territorio e i materiali*, edited by M. Bergamini. Florence.

Niccolini, A, Niccolini, F., and F. Niccolini. 1854. *Le case ed i monumenti di Pompei designati e descritti*. Vol 1. Naples.

Niccolini, A, Niccolini, F., and F. Niccolini. 1862. *Le case ed i monumenti di Pompei designati e descritti*. Vol 2. Naples.

Niccolini, A, Niccolini, F., and F. Niccolini. 1890. *Le case ed i monumenti di Pompei designati e descritti*. Vol 3. Naples.

Niccolini, A, Niccolini, F., and F. Niccolini. 1896. *Le case ed i monumenti di Pompei designati e descritti*. Vol 4. Naples.

Nylander, C. 1966. "Clamps and chronology. (Achaemenian problems II)." *Iranica Antiqua* 6: 130-146.

Oates, W.J. 1934. "The population of ancient Rome." *Classical Philology* 29.2: 101-116.

O'Connell, E. 2007. "Recontextualizing Berkeley's Tebtunis Papyri." In *Proceedings of the XXIVth International Congress of Papyrology, Helsinki 1–7 August 2004*, edited by J. Frösén et al., 2:807–26. Commentationes Humanarum Litterarum 122. Helsinki: Societas Scientiarum Fennica. Helsinki.

O'Connell, E., ed. 2014. "Catalogue of British Museum objects from The Egypt Exploration Fund's 1913/14 excavation at Antinoupolis (Antinoë)," with contributions by A. J. Dowler, Frances Pritchard, St John Simpson, Ross I. Thomas and André J. Veldmeijer. In *Antinoupolis* II: *Scavi e materiali* III, edited by R. Pintaudi, 467–504. Florence.

Olcese, G. 2012. *Atlante dei siti di produzione ceramica (Toscana, Lazio, Campania e Sicilia): con le tabelle dei principali relitti del Mediterraneo occidentale con carichi dall'Italia centro meridionale, IV secolo a.C.-I secolo d.C.* Rome.

Olcese, G. and C. Coletti. 2016. *Ceramiche da contesti repubblicani del territorio di Ostia.* Rome.

Orlandos, A.K. 1966. *Les matériaux de construction et la technique architecturale des anciens grecs*. Paris.

Orr, D.G. 1972. "Roman domestic religion: a study of the Roman household deities and their shrines at Pompeii and Herculaneum." Ph.D. dissertation, University of Maryland.

Packer, J.E. 1967. "Housing and population in imperial Ostia and Rome." *JRS* 57.1-2: 80-95

Packer, J.E. 1971. "The insulae of imperial Rome." *Memoirs of the American Academy* 31.

Packer, J.E. 1978. "Inns at Pompeii: a short survey." *Cronache pompeiane* 4: 5-53.

Pagliaro, F., Bukowiecki, E. Gugliermetti, F. and F. Bisegna. 2014. "The architecture of warehouses: a multidisciplinary study on thermal performances of Portus' Roman store buildings." *Journal of Cultural Heritage* 16.4: 560-566.

Pallecchi, S. 2005. *I mortaria di produzione centro-italica: corpus dei bolli.* Rome: Quasar.

Palmer, R. 2001. "Bridging the Gap: The Continuity of Greek Agriculture from the Mycenaean to the Historical Period," in *Prehistory and History: Ethnicity, Class, and Political Economy*, edited by. D. W. Tandy, 41–84. Montréal: Black Rose Books.

Parker, A. 1992. *Ancient shipwrecks of the Mediterranean and the Roman provinces*. BAR-IS 580. Oxford: Tempus Reparatum

Paroli, L. 1996. "Ostia alla fine del mondo antico: nuovi dati dallo scavo di un magazzino doliare," in *Roman Ostia revisited: archaeological and historical papers in honor of Russel Meiggs*, edited by A. Gallina Zevi, 249-264.

Pasqui, A. 1906. "Ostia - Nuove scoperte presso il Casone." *Notizie degli Scavi a'Antichità*: 357-373.

Pavolini, C. "A survey of excavations and studies on Ostia (2004-2014)." *JRS* 106: 199-236.

Peacock, D.P.S. and D.F. Williams. 1986. *Amphorae and the Roman economy: an introductory guide.* London.

Pecci, A., Clarke, J., Thomas, M., Muslin, J., van der Graaff, I., Toniolo, L, Miriello, D., Crisci, G.M., Buonincontri, M. and G. Di Pasquale. 2017. "Use and reuse of amphorae. Wine residues in Dressel 2-4 amphorae from Oplontis Villa B (Torre Annunziata, Italy)." *Journal of Archaeological Science: Reports* 12: 515-521.

Pecci, A., Giorgi, G., Salvini, S., and M.Á. Cau Ontiveros. 2013. "Identifying wine markers in ceramics and plasters using gas chromatography-mass spectrometry. Experimental and archaeological materials" *Journal of Archaeological Science* 40: 109-115.

Peña, J.T. 2007a. *Roman Pottery in the Archaeological Record.* Cambridge: Cambridge University Press.

Peña, J.T. 2007b. "A reinterpretation of two groups of *tituli picti* from Pompeii and environs: Sicilian wine, not flour and hand-picked olives." *JRA* 20: 233-254.

Peña, J.T. 2014. "The Pompeii Artifact Life History Project: conceptual background and first season's results." *Rei cretariae romanae fautorum acta* 43, 297-304.

Peña. J.T. and C. Cheung. 2015. "The Pompeii Artifact Life History Project: Conceptual Basis and Results of First Three Seasons," in proceedings of XIII International Forum Le Vie dei Mercanti, Aversa, Capri, June 11-13, 2015, 2115-2123.

Peña, J.T. and M. McCallum. 2009a. "The Production and Distribution of Pottery at Pompeii: A Review of the Evidence; Part 1, Production." *AJA* 113.1: 57 – 79.

Peña, J.T. and M. McCallum. 2009b. "The Production and Distribution of Pottery at Pompeii: A Review of the Evidence; Part 2, The Material Basis for Production and Distribution." *AJA* 113.2: 165 – 201.

Peña, J.T. 1998. "The mobilization of state olive oil in Roman Africa: the evidence of late fourth century ostraca from Carthage." In *Carthage papers: the early colony's economy, water supply, a public bath, and the mobilization of state olive oil*, edited by J.T. Peña, J.J. Rossiter, A.I. Wilson, and C. Wells, 116-238. Journal of Roman Archaeology supplementary series 28. Portsmouth, R.I.

Philippon, A. and L. Védrine. 2009. "Paysage urbain, patrimoine et musées. Le port antique de Marseille." *Les nouvelles de l'archéologie* 117: 40-46.

Pirandello, L. 1927. *La giara: novelle per un anno.* Verona.

Poehler, E. 2011. "Where to Park? Carts, Stables and the Economics of Transport in Pompeii." In *Rome, Ostia and Pompeii: Movement and Space*, edited by R. Laurence and D. Newsome, 194-214. Routledge.

Poehler, E. 2017. *The traffic systems of Pompeii.* Oxford University Press.

Poggessi, G. 2011. *Mura di cinta di Cosa : l'intervento di restauro 1999/2000*. Tecnostudio.

Price, J. 2005. "Glass-working and glassworkers in cities and towns." In *Roman working lives and urban living*, edited by A. MacMahon and J. Price, 167-190. Oxford.

Pullen, D.J., ed. 2010. *Political economy of the Aegean bronze age.* Oxbow books.

Purcell, N. 1985. "Wine and Wealth in Ancient Italy." *Journal of Roman Studies* 75: 1 – 19.

Purcell, N. 1994. "The city of Rome and the *plebs urbana* in the late Republic." *Cambridge ancient history* vol. 9, 644-688.

Purcell, N. 1996. "The Ports of Rome," in *'Roman Ostia' revisited: archaeological and historical papers in memory of Russell Meiggs*, edited by A.G. Zevi and A. Claridge. British School at Rome.

Rando, G. 1996. "Le antiche riparazioni in piombo sui *dolia* provenienti dal relitto della nave romana del Golfo di Diano Marina." *Atti del convegno internazionale della ceramic, Albisola superiore, maggio 1996*. http://www.pinorando.com/Atti/atti-convegno-albisola.pdf

Rathbone, D.W. 1981. "The development of agriculture in the *Ager Cosanus* during the Roman Republic: problems of evidence and interpretation." *Journal of Roman Studies* 71: 10-23.

Rebay-Salisbury, K., Brysbaert, A., and L. Foxhall, eds. 2015. *Knowledge networks and craft traditions in the ancient world: material crossovers*. New York.

Rehder, J.E. 2000. *The mastery and uses of fire: a sourcebook on ancient pyrotechnology*. Montreal.

Rice, C. 2016. "Shipwreck cargoes in the western Mediterranean and the organization of Roman maritime trade." *Journal of Roman Archaeology* 29: 165-192.

Richardson, L. 1992. *A new topographical dictionary of ancient Rome*. Baltimore and London.

Rickman, G. 1971. *Roman Granaries and Store Buildings*. Cambridge University Press.

Rickman, G. 1980. *The Corn Supply of Ancient Rome*. Cambridge University Press.

Rickman, G. 1996. "Portus in Perspective," in *'Roman Ostia' revisited: archaeological and historical papers in memory of Russell Meiggs*, edited by A.G. Zevi and A. Claridge. British School at Rome.

Rickman, G. 2002. "Rome, Ostia, Portus: the problem of storage." *Mélanges de l'école française de Rome* 114.1: 353-362.

Riley, 1999. *The Role of the Traditional Mediterranean Diet in the Development of Minoan Crete: Archaeological, Nutritional, and Biochemical Evidence*. BAR International Series 810. Oxford: British Archaeological Reports.

Robinson, D. and Wilson, A.I., eds. 2011. *Maritime Archaeology and Ancient Trade in the Mediterranean*. Oxford Centre for Maritime ArchaeologySalido Domínguez, J. 2011. *Horrea militaria : el aprovisionamiento de grano al ejército en el occidente del Imperio Romano*. Consejo Superior de Investigaciones Científicas.

Rodríguez Almeida, E. 1989. *Los tituli picti de las ánforas olearias de la Bética. I, Tituli picti de los Severos y la Ratio fisci*. Madrid.

Rodríguez Almeida, E. (1993). "Cellae Vinariae Nova et Arruntiana." In *Lexicon Topographicum Urbis Romae*, *1*, edited by E.M. Steinby, 259. Rome.

Rosenfeld, A. 1965. *The inorganic raw materials of antiquity*. New York and Washington.

Ross, L.A. 1985. "16th century Spanish Basque coopering." *Historical archaeology* 19.1: 1-31.

Rossiter, J.J. 1981. "Wine and Oil Processing at Roman Farms in Italy." *Phoenix* 35.4: 345-361.

Rotroff, S.I. 2011. "Mended in antiquity: repairs to ceramics at the Athenian agora." In *Pottery in the Archaeological Record: Greece and Beyond*, edited by M.L. Lawall and J. Lund, 117-134. Aarhus.

Rougé, J. 1966. *Recherches sur l'organisation du commerce maritime en Méditerranée sous l'empire romain*. Ecole pratique des hautes études. VIe section. Centre de recherches historiques 21. Paris.

Salido Domínguez, J. 2011. *Horrea militaria : el aprovisionamiento de grano al ejército en el occidente del Imperio Romano*. Consejo Superior de Investigaciones Científicas. Madrid.

Scheidel, W. 2001. "Roman age structure: evidence and models." *Journal of Roman Studies* 91: 1-26.
Scheidel, W. 2004. "Human mobility in Roman Italy, I: The free population." *Journal of Roman Studies* 94: 1-26.
Scheidel, W. 2005. "Human mobility in Roman Italy, II: The slave population." *Journal of Roman Studies* 95: 64-79.
Scheidel, W. 2007. "Demography." In *The Cambridge Economic History of the Graeco-Roman World*, edited by W. Scheidel, I. Morris, and R. Saller, 38-85. Cambridge University Press.
Scheidel, W., Morris, I. and R. Saller, eds. 2007. *The Cambridge Economic History of the Graeco-Roman World.* Cambridge University Press.
Schiffer, M. 1972. "Archaeological context and systemic context." *American Anthropologist* 37: 156-65.
Schiffer, M. 1996. *Formation processes of the archaeological record* (2nd edition). Salt Lake City.
Scott, A.R. 2008. *Cosa: the black-glaze pottery 2*. Memoirs of the American Academy in Rome. Ann Arbor: University of Michigan Press.
Scott, D.A. and Eggert, G. 2009. *Iron and Steel: Corrosion, Colorants Conservation.*
Scott, J.C. 2017. *Against the grain. Deep history of the earliest states.* Yale University Press.
Senatore, F. 1980. "*Ager Pompeianus:* viticoltura e territorio nella Piana del Sarno nel I sec. d.C.," in *Pompei il Sarno e la Penisola Sorrentina: atti del primo ciclo di conferenze di geologica, storia e archeologica*. Pompei: Rufus.
Sennett, R. 2008. *The craftsman*. New Haven.
Shryock, A. and D.L. Smail. 2018. "On containers: A forum. Introduction." *History and Anthropology* 29.1: 1-6.
Sirks, A.J.B. 1991. *Food for Rome: the legal structure of the transportation and processing of supplies for the imperial distributions in Rome and Constantinople*. J.C. Gieben.
Skibo, 1992. *Pottery function: use-alteration perspective.* New York.
Slane, K.W. 2011. "Repair and Recycling in Corinth and the Archaeological Record," in *Pottery in the Archaeological Record: Greece and Beyond*, edited by M.L. Lawall and J. Lund, 95-106. Aarhus University Press.
Slane, K.W. forthcoming. *Amphorae of Cosa.* Ann Arbor.
Smith, M.E. 2004. "The Archaeology of Ancient State Economies." *Annual Review of Anthropology* 3: 73-102.
Sogliano, A. 1888. "Pompei. Degli edificii recentemente scoperti, e degli oggetti raccolti negli scavi dal dicembre 1887 al giugno 1888. Relazione dell'ispettore prof. A. Sogliano." *Notizie degli Scavi d'Antichità* 13: 509-530.
Sogliano, A. 1889. "Pompei. Degli edificii recentemente coperti e degli oggetti raccolti negli scavi dal settembre 1888 al marzo 1889. *Notizie degli Scavi d'Antichità* 14: 114-136.
Soroka, W. 1995. *Fundamentals of packaging technology*. Institute of Packaging Professionals.
Spanu, M. 2015. "Un *mortarium* con bollo doliare urbano da Narmouthis (Medinet Madi)." *Analecta papyrological* 27: 177-183.

Steinby, E.M. 1998. "Ricerche sull'industria doliare nelle aree di Roma and e Pompei: un possibile modello interpretativo," in *I Laterizi di Età Romana nell'Area Nordadriatica*, edited by C. Zaccaria, 9-14. L'Erma di Bretschneider.

Stern, E.M. 2008. "Glass production." In *The Oxford handbook of engineering and technology in the classical world,* edited by J.P. Oleson, 520-550. Oxford.

Stern, E.M. 1999. "Roman glassblowing in a cultural context." *American Journal of Archaeology* 103.3: 441-484.

Stevens, S. 2005. "Reconstructing the garden houses at Ostia. Exploring water supply and building height." *Bulletin van de Antieke Beschaving* 80: 113-123.

Stiros, S.C. 1995. "Archaeological evidence of antiseismic constructions in antiquity." *Annali di Geofisica* 38.5-6: 725-736.

Stone, D.L. 2009. "The Distribution of Stamped Amphoras from *Byzacena*." In *Studies on Roman pottery of the provinces of Africa Proconsularis and Byzacena (Tunisia): homage à Michael Bonifay*, edited by J.H. Humphrey, 127-150. Portsmouth, R.I.

Storey, G. 1997. "The population of ancient Rome." *Antiquity* 71: 966-978.

Storey, G. 2001. "Regionaries-type insulae 1: architectural/residential units at Ostia." *AJA* 105.3: 389-401.

Storey, G. 2002. Regionaries-type insulae 2: architectural/residential units at Rome." *AJA* 106.3: 411-434.

Storey, G. 2004. "The meaning of 'insula' in Roman residential terminology." *Memoirs of the American Academy in Rome* 49: 47-84.

Strickland, M. 2016. "Why refrigerators were so slow to catch on in China." *The Atlantic, object lessons* series, (May 4, 2016), accessed on February 4, 2018 from https://www.theatlantic.com/technology/archive/2016/05/why-refrigerators-were-so-slow-to-catch-on-in-china/481029/.

Sundelin, L.K.R. 1996. "Plaster jar stoppers."In *Berenike 1995. Preliminary report of the 1995 excavations at Berenike (Egyptian Red Sea Coast) and the survey of the Eastern Desert*, edited by S.E. Sidebotham and W.Z. Wendrich, 297-308. Leiden.

Taglietti, F. 2015. "*Dolia* e coperchi di *dolia*: problematici assortimenti." In *Opus Doliare Tiberinum: atti delle giornate di studio (Vitero 25-26 ottobre 2012)*, edited by M. Spanu, 267-29. Viterbo.

Tan, J. 2017. *Power and Public Finance at Rome, 264-49 BCE.* Oxford University Press.

Tchernia, A. 1986. *Le vin de l'Italie romaine. Essai d'histoire économique d'après les amphores.* Bibliothèque des Écoles françaises d'Athènes et de Rome.

Tchernia, A. 1997. "Le tonneau, de la bière au vin." In *Techniques et économie antiques et médiévales. Le temp de l'innovation*, edited by Garcia and Meeks, 121-129. Paris.

Tchernia, A. 2016. *The Romans and trade*. Oxford University Press.

Thomas, M.L. 2015. "Oplontis B: a Center for the Distribution and Export of Vesuvian Wine." *JRA* 28: 403-412.

Thomas, M.L., van der Graaff, I., P. Wilkinson. 2013. "The Oplontis Project 2012-2013: A Report of Excavations at Oplontis B." *Journal of Roman Archaeology*

Thomas, R.I. and R. Tomber. 2006. "Vessel Stoppers." In *Mons Claudianus: 1987-1993. Survey and Excavation. Volume III. Ceramic Vessels and Related Objects,* edited by V. Maxfield and D. Peacock, 239-258. Fouilles de l'IFAO 54. Cairo, Institut français d'archéologie orientale.

Thomas, R.I. 2011. "Roman vessel stoppers." In *Myos Hormos – Quseir al-Qadim. Roman and Islamic Ports on the Red Sea. Volume 2: Finds from the Excavations 1999-2003,* edited by D. Peacock and L. Blue, 11-34. British Archaeological Reports International Series 2286. University of Southampton Series in Archaeology 6. Oxford.

Thomas, R.I. 2014. Nos 1–10, 42, 46–58. In Catalogue of British Museum objects from The Egypt Exploration Fund's 1913/14 excavation at Antinoupolis (Antinoë), edited by E. R. O'Connell with contributions by A. J. Dowler, F. Pritchard, St J. Simpson, R. I. Thomas and A. J. Veldmeijer. In *Antinoupolis* II: *Scavi e materiali* III, edited by R. Pintaudi, 467–504. Florence.

Thornton, J. 1998. "A brief history and review of the early practice and materials of gap-filling in the west." *Journal of the American Institute for Conservation* 37: 3-22.

Thurmond, D.L. 2006. *A handbook of food processing in classical Rome. For her bounty no winter*. Brill.

Tol, G. and B. Borgers. 2016. "The study of local production and exchange in the lower Pontine plain." *Journal of Roman Archaeology* 29.1: 349-370.

Twede, D. 2002a. "Commercial Amphoras: the Earliest Commercial Packaging?" *Journal of Macromarketing* 22(1): 98-108.

Twede, D. 2002b. "The Packaging Technology and Science of Ancient Transport Amphoras." *Packaging Technology and Science*. 15.4: 181-195.

Twede, D. 2005. "Baskets, Barrels and Boxes: The History of Wooden Shipping Containers." *22nd IAPRI Symposium Proceedings*. Campinas, Brazil: Centro de Tecnologia de Embalagem.

Twede, D. 2009. "Packaging Economics." In *Wiley Encyclopedia of Packaging Technology*, 3rd edition, edited by K. Yam, 383-389. New York: Wiley Interscience.

Twede, D. and Harte, B. 2011. "Logistical Packaging for Food Marketing Systems." In *Food and Beverage Packaging Technology*, 2nd edition, edited by R. Coles and M. Kirwan, 85-105. Chichester, UK: Wiley/Blackwell.

Twede, D., Clarke, R. and J. Tait. 2000a. "Packaging Postponement: A Global Packaging Strategy." *Packaging Technology and Science* 13.3: 105-115.

Twede, D., Clarke, R. and J. Tait. 2000b. "Perspective on a Global Packaging Strategy - Packaging Postponement." *Journal for Packaging Professionals*. 1.1: 15-18.

Uboldi, M. 2005. "Laterizi e opus doliare." In *La ceramica e i materiali di età romana. Classi, produzioni, commerci e consumi*, edited by D. Gandolfi, 479-490. Scuola Interdisciplinare delle Metodologie Archeologiche, Bordighera.

Ulrich, R.B. 2007. *Roman woodworking*. New Haven and London.

Ural, A. and S. Uslu, S., 2014. “Shear tests on stone masonry walls with metal connectors.” *European Journal of Environmental and Civil Engineering* 18.1: 66-86.

Vaccaro, E., Ghisleni, M., Arnoldus-Huyzendveld, A., Grey, C., Bowes, K., MacKinnon, M., Mercuri, A.M., Pecci, A., Cau Ontiveros, M.A., Rattigheri, E. and R. Rossella Rinaldi. 2013. “Excavating the Roman peasant II: excavations at Case Nuove, Cinigiano (GR).” *Papers of the British School in Rome* 81: 129-179, 408-413.

van Andel, T.H. and C. Runnels. 1987. *Beyond the Acropolis: A Rural Greek Past.* Stanford University Press.

van der Veen, M. 2008. “Food as embodied material culture: diversity and change in plant food consumption in Roman Britain.” *Journal of Roman Archaeology* : 83-109.

van der Veen, M. and G. Jones. 2006. “A re-analysis of agricultural production and consumption: implications for understanding the British Iron Age.” *Veget. Hist. Archaeobot.* 15: 217-228.

van der Veen, M. and T. O’Connor. 1998. “The expansion of agricultural production in late Iron Age and Roman Britain.” In *Science in archaeology, an agenda for the future*, edited by J. Bayley, 127-144. English Heritage.

Van der Werff, J. 1989. “Sekundare graffiti auf römischen Amphoren,” *Archäologische Korrespondenzblatt* 19: 361-76.

Van der Werff, J. 2003. “The second and third lives of amphoras in Alfen Aan Den Rijn, the Netherlands.” *Journal of Roman Pottery Studies* 10: 109-16.

Vandorpe, K. 2005. “Sealing containers in Greco-Roman Egypt. The inscriptional and papyrological evidence.” In *Oggetti in argilla dall’area templare di Bakchias (El-Fayyum, Egitto): catalogo dei rinvenimenti delle campagne di scavo 1996-2002*, edited by P. Davoli, 163-175. Pisa.

Van Driel-Murray, C. 2008. “Tanning and leather.” In *The Oxford handbook of engineering and technology in the classical world,* edited by J.P. Oleson, 483-495. Oxford.

Van Oyen, A. 2015a. “The moral architecture of villa storage in Italy in the 1st c. BC.” *Journal of Roman Archaeology* 28: 97-123.

Van Oyen, A. 2015b. “The Roman city as articulated through terra sigillata.” *Oxford Journal of Archaeology* 34(3): 279-299.

Van Oyen, A. and M. Pitts, eds. 2017a. *Materialising Roman Histories.* Oxford and Philadelphia.

Van Oyen, A. and M. Pitts. 2017b. “What did things do in the Roman world? Beyond representation.” In *Materialising Roman Histories*, edited by A. Van Oyen and M. Pitts, 3-20. Oxford and Philadelphia.

Vitali, D., ed. 2007. *Le fornaci e le anfore di Albinia. Primi dati su produzioni e scambi dalla costa tirrenica al mondo gallico. Atti del seminario internazionale. Ravenna. 6-7 maggio 2006*. Bologna.

Vitelli, G. 1980. “Grain storage and urban growth in imperial Ostia: a quantitative study.” *World archaeology* 12.1: 54-68.

Wallace-Hadrill, A. 2008. *Rome’s Cultural Revolution*. Cambridge University Press.

Warscher, T. 1935-1960. “Codex Topographicus Pompeianus.” Rome.

Weller, J. 1999. "Roman traction systems." http://www.humanist.de/rome/rts/index.html

Wells, B., ed. 1992. *Agricultural in Ancient Greece: Proceedings of the Seventh International Symposium at the Swedish Institute in Athens, 16-17 May 1990*. Stockholm: Swedish Institute in Athens.

Wendrich, W. 2012. "Recognizing knowledge transfer in the archaeological record." In *Archaeology and apprenticeship: body knowledge, identity, and communities of practice*, edited by W. Wendrich, 255-262. Tucson: University of Arizona Press.

Wendrich, W., ed. 2012. *Archaeology and apprenticeship: body knowledge, identity, and communities of practice.* Tucson: University of Arizona Press.

White, K.D. 1975. *Farm Equipment of the Roman World.* Cambridge.

White, P. 2016. "Qvevri culture." *The World of Fine Wine* 53: 117-123.

Will, E.L. 1987. "The Roman Amphoras," in *The Roman Port and Fishery of Cosa*, edited by A.M. McCann. Princeton.

Wilson, A.I. 2008. "Hydraulic Engineering." In *Handbook of Engineering and Technology in the Classical World,* edited by J.P. Oleson, 285-318. Oxford University Press.

Wilson, A.I 2009. "Indicators for Roman Economic Growth: A Response to Walter Scheidel." *Journal of Roman Archaeology* 22: 71-82.

Wilson, A.I 2011a. "Developments in Mediterranean shipping and maritime from the Hellenistic period to AD 1000," in *Maritime Archaeology and Ancient Trade in the Mediterranean*, edited by D. Robinson and A. Wilson, 33-59, Oxford Centre for Maritime Archaeology Monograph 6. School of Archaeology: Oxford.

Wilson, A.I 2011b. "Developments in Mediterranean shipping and maritime trade from the Hellenistic Period to AD 1000," in *Maritime Archaeology and Ancient Trade in the Mediterranean*, edited by D. Robinson and A. Wilson, 33-60. Oxford Center for Maritime Archaeology.

Witcher, R. 2005. "The extended metropolis: urbs, suburbium and population." *Journal of Roman archaeology* 18: 120-138.

Witcher, R. 2006. "Settlement and society in early imperial Etruria." *Journal of Roman Studies* 96: 88-123.

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

Wootton, W., Russell, B., and P. Rockwell 2013. 'Stoneworking techniques and processes (version 1.0)', The Art of Making in Antiquity: Stoneworking in the Roman World. http://www.artofmaking.ac.uk/content/essays/3-stoneworking-techniques-and-processes-w-wootton-b-russell-p-rockwell/

Work, H.H. 2014. *Wood, whiskey and wine. A history of barrels.* Chicago.

Work, H.H. 2014. *Wood, whiskey, and wine. A history of barrels.* Reaktion Books.

Yadin, Y. 1963. *Finds from the Bar Kokhba period in the Cave of Letters.* Jerusalem.

Yam, K.L., ed. 2009. *Encyclopedia of packaging technology.* Third edition.

Zimmer, G. 1982. *Roemisches Berufsdarstellungen.* Gebrüder Mann Verlag.

Appendix. Descriptions of Select Dolia from Cosa, Pompeii, and Ostia.

Cosa

Cosa no 1. Rim fragment from a large dolium, featuring modification made during use life.
ID number: CD 707, 550. Cosa Catalog Card: Incorrectly identified as rim of a mortar. Found on June 21, 1951 in square VIII D Bas. ENW 2 Level II.
Date: Last quarter of the second century BCE to first quarter of the first century BCE (reused).
Description: Rim fragment from large dolium; three iron screws were drilled into the upper surface of the rim, one of which was connected to a thin strip of lead shallowly engraved into the vessel surface.
Dimensions: Rim external diameter c. 70 cm (19% preserved), rim internal diameter 48 cm. Length c. 34 cm. Wall thickness 5.04 cm. Munsell: 5YR 6/8 reddish yellow; very few inclusions.
Modifications: Three iron (?) nails were drilled into the upper face of the rim; dimensions of nail 1 2.2 x 1.5 cm, nail 2 2.1 x 1.5 cm, nail 3 2.3 x 1.4 cm. One nail (at the end) was connected to a thin strip of lead placed in a shallow cutting in the vessel surface; metal strip length 1.642 cm, width 0.4-0.48 cm, depth 0.32 cm. These modifications were executed during the vessel's use-life.

Cosa no. 11. Rim fragment of large dolium, repaired.
ID number: C14.1000; 2014 Western Castellum Sounding 2, SU 10003 (puteal), found on June 25, 2014.
Date: First or second century CE (reused for construction).
Description: Rim fragment of large dolium featuring two impressions of interventions.
Dimensions: Rim external diameter 80 cm, internal diameter 55 cm (12% preserved).
Interventions: two different interventions on opposing sides of the fragment. One is the preserved cutting for half a double dovetail with small traces of lead; unclear whether this was made during the production-phase or use-life. The other intervention features the preserved half of a drill hole through rim, which was probably executed during use-life to form modifications similar to Cosa no. 1.

Cosa no 19. Three large joining fragments of large dolium.
ID number: 213445.
Date: First century CE.
Description: Joining fragments of large dolium rim, shoulder, and middle wall; feature repairs on dolium shoulder.
Dimensions: rim exterior diameter c. 76 cm, interior diameter c. 50 cm (c. 50% preserved), wall thickness 5.6 cm.
Repairs: Three hybrid clamp and mortise-and-tenon repairs of lead arranged in horizontal alignment on upper shoulder of vessel where crack formed between two coils. Settings for the clamps on the exterior wall were carved into the vessel wall, whereas the cross bars of the clamps on the interior wall of the vessel lied on the surface of the vessel. Two of the clamps

were similar in execution, featuring a stylized border for the clamp surface on the exterior wall. The third clamp is smaller, with somewhat asymmetrical form and rougher edges and no stylized border. The three clamps were made during the vessel's use-life; based on the form and execution, two of the three clamps were made at the same time and probably by the same person, whereas one clamp was probably at a different time and by a different person.
Stamp: A small (4.7 x 1.8 cm) stamp, *C.TVRI*, preserved on rim.
Incisions: A symbol (8.4 x 8.2 cm, 0.2 cm deep), possibly of an anchor, incised onto shoulder of vessel.

Cosa no. 29. Fragment of dolium base, with repairs.
ID number: C 70 V D SH St. S. 5, M L 0.I K Ware
Date: First half of the first century BCE.
Description: Base fragment of medium or small dolium preserving 16% of the base and a portion of the lower wall; repaired.
Dimensions: base diameter 25 cm, base height 2.4 cm, wall thickness 3.6 cm. Munsell 7.5R 6/8 light red.
Repairs: Lead hybrid double dovetail tenon and clamp repair on base and lower wall, almost certainly made during use-life of vessel. On exterior surface, base had double dovetail connected to a tenon that extended from the base onto the lower wall of the well. The base was drilled through to insert a pin that connected the double dovetail on the underside of the base to a clamp on the interior surface of the base. Double dovetail and clamp made of lead; traces of lead visible on tenon.

Cosa TC. Terracotta object, featuring repair.
ID number: CB 1176.
Date: First century BCE.
Description: Fragment of terracotta object (dolium or architectural terracotta), repaired.
Dimensions: wall thickness 3.6 cm.
Repairs: Large clamp made of very dark material (possibly iron with lead), added during the object's use-life. One side of clamp consistent and flat, other side highly irregular. The clamp was uneven and not neatly executed, with large space left between pins. Cracks radiate from the drill holes.

Pompeii

All dolia dated to 79 CE.

I.21.2
This is the house connected to the Garden of the Fugitives, where thirteen (?) Pompeians perished in their attempt to flee from the eruption. The room connected to the garden had an area with a treading vat and three dolia for wine production.

I.21.2 no. 1 Large, intact dolium, missing rim.
Description: Nearly complete and intact dolium, missing entire rim and almost all of rim core. The dolium features two sets of repairs made during the production phase; one set consisted

of at least three double dovetails on shoulder and the second set is a vertical double dovetail tenon on the shoulder.
Dimensions: Preserved height 76+ cm; maximum diameter of vessel c. 84 cm; wall thickness 3.0-3.5 cm.
Repairs: On one area of vessel shoulder are (1) three lead double dovetails, one another area of vessel shoulder is part of a (2) vertical lead double dovetail tenon with three double dovetails (lead mostly missing); both sets of repairs were made during the production-phase. The repairs were all neatly and consistently executed, and were probably cut (than than 1 cm deep) into the vessel surface when the dolium was leather-hard. The (1) double dovetails are c. 8-9 cm long x c. 3 cm wide, with a width at the middle of c. 1.5 cm. The (2) double dovetail tenon probably extended from the rim (now missing) to the middle wall; 35 cm of its length and three double dovetails (c. 9-10 cm x 3 cm) are preserved.

I.21.2 no. 2 Large, nearly complete, intact dolium.
Description: Large intact dolium, complete except for small chip off rim lip. Dolium features two sets of repairs on vertical dunting cracks.
Dimensions: Preserved height 83 cm; maximum diameter of vessel c. 93 cm. Exterior rim diameter 53 cm, interior rim diameter 31 cm.
Repairs: Two vertical sets of lead (alloy?) repairs opposite one another, extending from upper face of rim to upper vessel wall. One set consists of a hybrid mortise-and-tenon staple on rim face, with two clamps followed by a triangular clamp on upper wall. Second set has a hybrid mortise-and-tenon staple on rim face, a clamp on juncture between rim and shoulder, and two clamps on upper wall. All repairs, except for the clamp on the juncture between rim and shoulder, were probably made at the same time, perhaps in the workshop during the production-phase; they are similar to one another in dimensions and material. The clamps (c. 9-10 cm x 1 cm) on the upper wall might have been drilled when the vessel was leather-hard, or after firing. The hybrid mortise-and-tenon staples on the rim were an attempt to repair dunting cracks that had formed during firing, and were probably formed in the workshop. They are the same shape and are filled with the same material; the minor differences between their dimensions are probably the result of difficulty in chiseling into an already fired ceramic surface (9.4 x 2.0 cm; 11.7 x 1.7cm). The lead clamp (13 x 1 cm) on the juncture between the rim and shoulder was likely added later, during use-life.

I.22.
The House of Stabianus was excavated several times during the 20th century. Wilhelmina Jashemski's excavations revealed that the property was a large olive tree orchard at the time of the eruption. Subsequent excavations in the 1980s, never published, uncovered several dolia. Because many of the dolia are below the layer of lapilli where several Pompeians died during the eruption, the dolia remain buried to preserve the plaster casts of the bodies in-situ. At the time of the eruption, the House of Stabianus was undergoing renovations, and the dolia were being reused to hold construction materials. They were probably originally for wine fermentation and storage.

I.22 no. 1. Large dolium, repaired.
Description: Large dolium buried in lapilli, only one small area with a repair visible.

Dimensions: None could be taken.
Repairs: Single, thin vertical lead fill on dolium (upper?) wall.

I.22 no. 3. Large dolium, repaired.
Description: Large dolium, partly buried in lapilli; the base and most of the vessel wall is visible, but rim and shoulder are under lapilli. The dolium was repaired in several areas.
Dimensions: Preserved height 1.10 m, base diameter 21 cm, wall thickness 3.3 cm.
Repairs: Numerous production-phase repairs on vessel, metal is lead alloy. Two sets of vertical double dovetail tenons preserved on vessel middle and upper walls (probably extended from rim to middle wall, but rim is buried under lapilli); the double dovetail tenons repaired vertical dunting cracks. Single double dovetail on vessel shoulder to repair crack between coils; horizontal set of double dovetails on middle wall, with additional clay smeared between double dovetails on emerging crack.

I.22 no. 5. Large dolium, repaired.
Description: Large dolium, partly buried in lapilli; most of the vessel is visible, part of the upper wall is still buried in lapilli. The dolium was probably repaired.
Dimensions: Height 1.32 m, exterior rim diameter 72 cm, interior rim diameter 44 cm, base diameter 21 cm, wall thickness 3.6 cm, volume 732 liters (calculation by Stanley Chang).
Repairs: Faint remains of cutting for double dovetail (metal missing) preserved on upper wall.

I.22 no. 7. Medium dolium, repaired.
Description: Medium sized dolium, repaired. A large horizontal crack formed on the vessel's middle wall and was repaired.
Dimensions: Height 0.94 m, exterior rim diameter 47 cm, interior rim diameter 28.5 cm, exterior belly diameter 75 cm, interior belly diameter 69 cm, base diameter 22 cm, volume 192 liters (calculated by Stanley Chang).
Repairs: Large hybrid repair on vessel's middle wall made during the vessel's use-life either at one time or in two stages. The repairer drilled three or four sets of holes on either side of the break and chiseled cuttings for double dovetail tenon. The repairer added lead to the crack and drill holes and the a wrought iron bar onto the lead placed in the break. The repairer then added a dark metal substance (lead alloy?) to fill the cutting for the double dovetail tenon. This use-life repair was probably an attempt to form a repair similar to production-phase double dovetail tenons, that required adaptations to methods.

I.22 no. 9. Medium dolium.
Description: Medium dolium, containing lapilli, rim broken (c. 45% preserved).
Dimensions: Height 84 cm, exterior rim diameter 48.5 cm, interior rim diameter 29.5 cm, exterior belly diameter 77 cm, base diameter 19 cm, wall thickness 3.5 cm, volume 133 liters (calculated by Stanley Chang).

I.22 no. 18. Fragment of repaired dolium.
Description: Body fragment of dolium that had been repaired with clamps in antiquity.
Dimensions: Wall thickness 4 cm.

Repair: Preserved on the dolium wall are (1) half a drill hole and (2) a drill hole filled with a lead pin leg, crossbar not preserved. The holes are preserved halves of two clamps. The repairer drilled through the vessel wall to form clamps during the dolium's use-life. Cracks formed around the (2) drill hole, and the dolium fragmented and broke halfway through the (1) drill hole, suggesting that the repairs were not effective and/or further damaged the vessel.

II.5.5
This large property, directly across from the amphitheater, was a vineyard with a wine press, cella vinaria, and large masonry triclinium. The wine press room was connected to the cell vinaria, and at least four lead pipes directed the must from the pressed grapes into some of the dolia. The cella vinaria was a long, narrow room with five dolia installed on either side of a path through the room. The dolia are all buried up to the shoulder or rim.

II.5.5 no. 10. Complete, intact large dolium, repaired.
Description: Dimensions: interior rim diameter 49 cm, exterior rim diameter 77 cm; depth of vessel 116 cm, interior belly diameter c. 120 cm.
Repairs: The dolium rim was heavily repaired with lead, almost all made during production. Three single double dovetails and three double dovetail tenons were neatly formed on the rim to repair dunting cracks, during the production phase. A large area of the rim surface (c. 5 x 20 cm) had been abraded or damaged, and was repaired with lead fill; unclear whether this was made during production or use.

II.8.6. Garden of Hercules.
The Garden of Hercules was a modest house attached to a commercial flower garden; the property was likely a perfume production facility. The commercial flower garden was installed with several dolia to collect and store rainwater for irrigation.

II.8.6 no. 1. Large, intact dolium, heavily repaired.
Dimensions: preserved height c. 1.25 m; exterior rim diameter 72 cm, interior rim diameter 44 cm; diameter of belly 117 cm.
Description: Large dolium that features many repairs; the dolium had been placed on top of a supportive base mostly made of stone, with one inverted fragment of a dolium rim. The dolium was probably originally for wine fermentation and storage, but was reused as a water container.
Repairs: numerous repairs having been executed on different parts of the vessel, mostly made during the production-phase of the vessel. Two lead alloy double dovetails on upper surface of rim, placed on opposite sides of one another to repair dunting cracks that formed on rim. Also placed on opposite sides of one another were two vertical sets of hybrid clamp mortise-and-tenon repairs on dolium body, almost certainly made during the production phase. A small set of horizontal lead alloy clamps were placed on the middle dolium wall and another set near the base. Repairers (probably members of the workshop) regularized the emerging vertical cracks and drilled holes on either side of the crack; after firing the dolium, they added lead alloy to the regularized crack and formed clamps. In one area, repairers chiseled a double dovetail (after firing) to add to the hybrid clamp repair, perhaps because the regularization was not sufficient in that area.

VI.14.36. Caupona of Salvius

This street corner caupona featured an upstairs area and multiple rooms, including a kitchen behind the room on the street. The room on the street had a masonry counter, in which two cylindrical jars were installed, and a cylindrical jar buried in the ground by the counter and a dolium buried in the ground by one of the entrances.

VI.14.36 no. 4. Medium spherical dolium in northwest corner of room.

Description: Complete, intact, well-preserved medium dolium. General surface abrasion on rim surface, some gouges on exterior wall of belly, three dunting cracks forming on rim into middle wall. Rim stamped during production-phase.

Dimensions: Preserved depth 47 cm, exterior rim diameter 44 cm, interior rim diameter 27 cm, exterior belly diameter 76 cm, interior belly diameter 66 cm.

Stamps: 5.6 x 2.0, letter size 0.7 cm. Two registers C.NAEVI/VITALIS

Surrounded by oval seal 1.8 x 1.3 cm

CIL X 8047, 11b

VI.14.27. House of Memmius Auctus.

This was a small, narrow house belonging to M. Memmius Auctus (*CIL* X 8058, 50), who is believed to have been a *vinarius* (wine dealer). In the back of the house was a small room where four dolia were buried, now only three visible.

VI.14.27 frag. 1

Description: Body fragment from a dolium, with evidence of ancient repair.

Repair: Single drill hole through wall of body fragment, made during the production-phase before the vessel was fired in the kiln. The drill hole was for a clamp, probably made of lead but no longer preserved.

Villa of the Mysteries.

Known for its wall-paintings and *pars urbana*, the Villa of the Mysteries had a significant *pars rustica* that included a wine press room with one dolium defeossum (no. 1) and a *cella vinaria* with three dolia defossa (nos. 2-4).

Villa of the Mysteries, no. 3. Mostly complete, intact dolium, heavily repaired.

Description: Large dolium defossum outside wine press room, features many repairs.

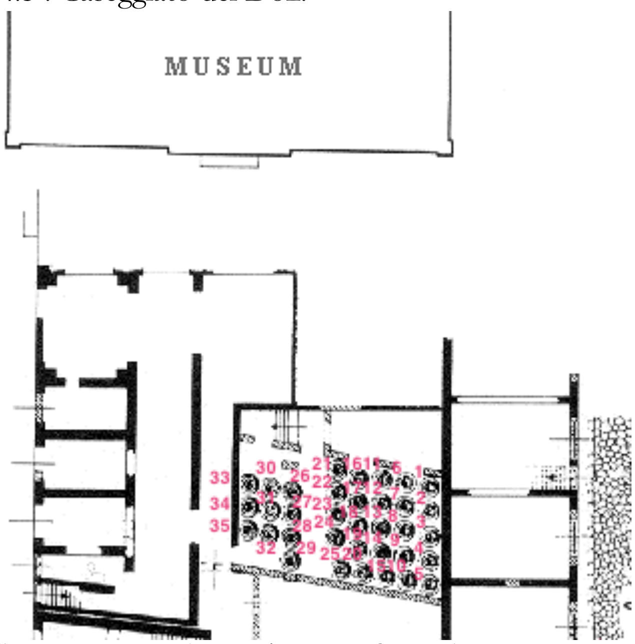
Dimensions: Exterior rim diameter 73 cm, interior rim diameter 46 cm, exterior belly diameter 110 cm.

Repairs: Numerous repairs on the rim, shoulder, and upper wall of the vessel, extending into the middle wall (and probably further below what is visible). On rim four dovetail-type repairs were preserved, a fifth broken. Three of the double dovetails on the rim were neatly executed during production. Two of the double dovetail repairs were hybrid double dovetail staples or clamps made after-firing (either in the workshop in the last phase of production or while in use). All five dovetails were part of vertically aligned set of double dovetails to correct dunting cracks, usually had two or three double dovetails on upper wall/shoulder; one was above a double dovetail tenon. One long horizontal double dovetail tenon, with at least six double dovetails, on shoulder for horizontal crack; mostly lead maybe a small portion of stronger metal. Very shallow 0.5-0.6 cm deep and consistent in form and size.

Ostia

All dolia at Ostia were installed during the first quarter of the second century CE; all volumes based on ancient inscriptions in units of amphorae.

I.4.5 . Caseggiato dei Doli.



The storeroom, located across from the museum, was built and installed with thirty five dolia during the first quarter of the second century CE. The dolia were probably used to store wine, but the dolia and the storeroom fell out of use by the end of the second or beginning of the third century CE.

I.4.5 no. 1. Large, intact dolium.
Description: Large, intact dolium with a repair.
Dimensions: Exterior rim diameter 104 cm, interior rim diameter 73 cm, exterior belly diameter 130 cm, volume 1102 liters.

Repairs: One lead double dovetail on the upper face of the rim to repair dunting crack, made during production. Length 12.5 cm, width of ends 3.4 cm and 3.2 cm, width in middle 1.7 cm.
Inscription: Two inscriptions visible, one on rim, one on upper shoulder: XLII ƆIII

I.4.5 no. 12. Large dolium, repaired.
Description: Large, intact dolium with a few dunting cracks repaired in antiquity.
Dimensions: Exterior rim diameter 99 cm, interior rim diameter 67 cm, exterior belly diameter 145 cm, volume 1101.5 liters.

Repairs: One vertical double dovetail tenon from rim to shoulder (or beyond) of vessel, unevenly preserved. On the rim upper surface was the impression of a double dovetail, c. 1.0 cm deep, metal not preserved. Under the rim lip is a vertical tenon, consisting of mostly lead, terminating in a double dovetail; c. 1.2 cm deep and 1.5 cm wide. Repair made during the production-phase.

Inscriptions: One inscription on upper shoulder: XLIIↃIII

I.4.5 no. 16. Large dolium.
Description: Large, intact dolium.
Dimensions: Exterior rim diameter 104 cm, interior rim diameter 70 cm, exterior belly diameter 130 cm, volume 1061 liters.
Repairs: None apparent.
Inscriptions: One inscription on upper shoulder: XLS

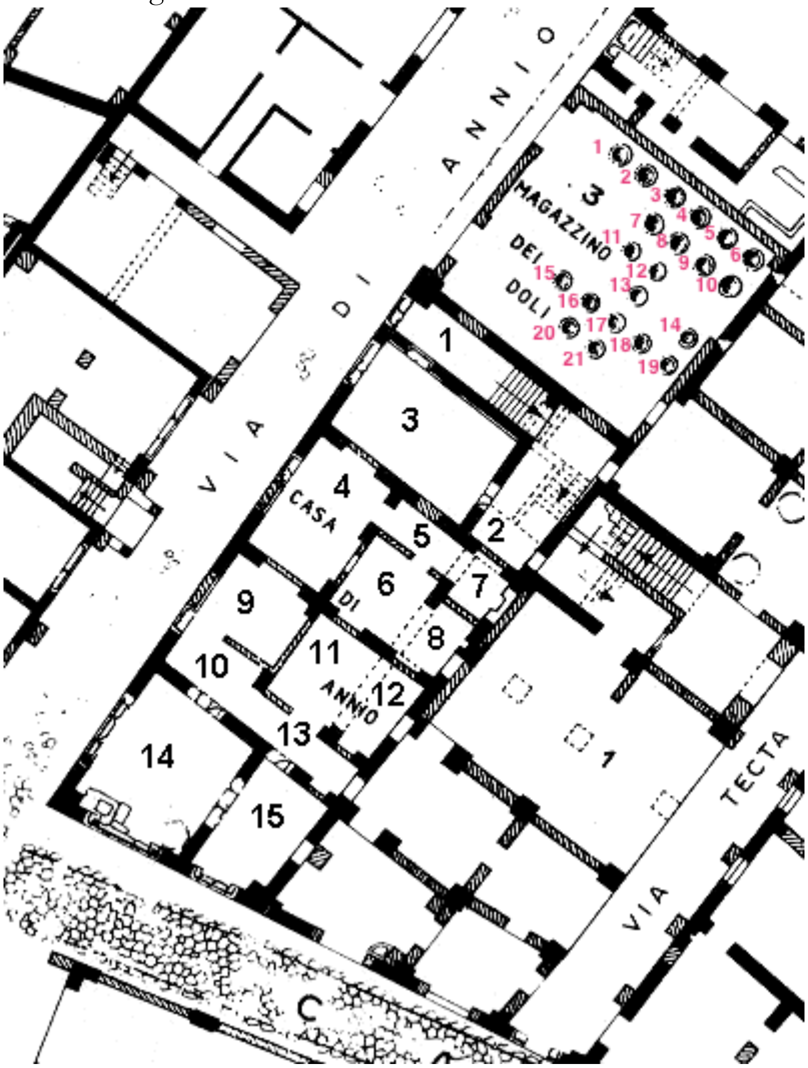
I.4.5 no. 17. Large dolium, repaired.
Description: Large intact dolium. Dunting cracks repaired in antiquity. Stamp on dolium rim.
Dimensions: Exterior rim diameter 96 cm, interior rim diameter 63 cm, exterior rim diameter 134 cm, volume 1100 liters.
Repairs: Two lead alloy double dovetail tenons on rim and shoulder. One double dovetail tenon was reinforced with a lead alloy strip. One end of the strip latched onto the underside of the rim lip and the other end of the strip latched onto the inner surface of the rim. On the exterior upper wall near one double dovetail tenon were two short vertical lead alloy fills.
Inscriptions: Two inscriptions, one on upper shoulder, one on rim. XLII
Stamp:

I.4.5 no. 18. Large dolium, repaired.
Description: Large dolium, broken, missing rim and most of shoulder. Dolium repaired.
Dimensions: Wall thickness 4.8 cm, exterior belly diameter 125 cm.
Repairs: A shallow lead alloy fill (14 x 1.5 cm) on exterior wall, diagonally oriented.
Inscriptions: None apparent.

I.4.5 no. 28. Dolium, repaired in antiquity.
Description: Repaired dolium, smaller than other dolia found at Ostia, with a different fabric (more red and with fewer inclusions). Small part of the rim (c. 25%) missing.
Dimensions: Exterior rim diameter 67 cm, interior rim diameter 45.5 cm, exterior belly diameter 110 cm, volume 774 liters.
Repairs: Horizontal lead double dovetail tenon around entire shoulder of vessel, connected to vertical double dovetail tenons, placed on opposite sides of the vessel, that extended the repair from the shoulder of the vessel to just under the rim. On rim at break, above one vertical double dovetail, is preserved half a lead double dovetail. Repairs were neat and consistent, and were made during the production-phase.

Inscriptions: One on upper shoulder at 11 o'clock. 'XXIXSC/ↃII'

III.14.3. Magazzino dei Doli.



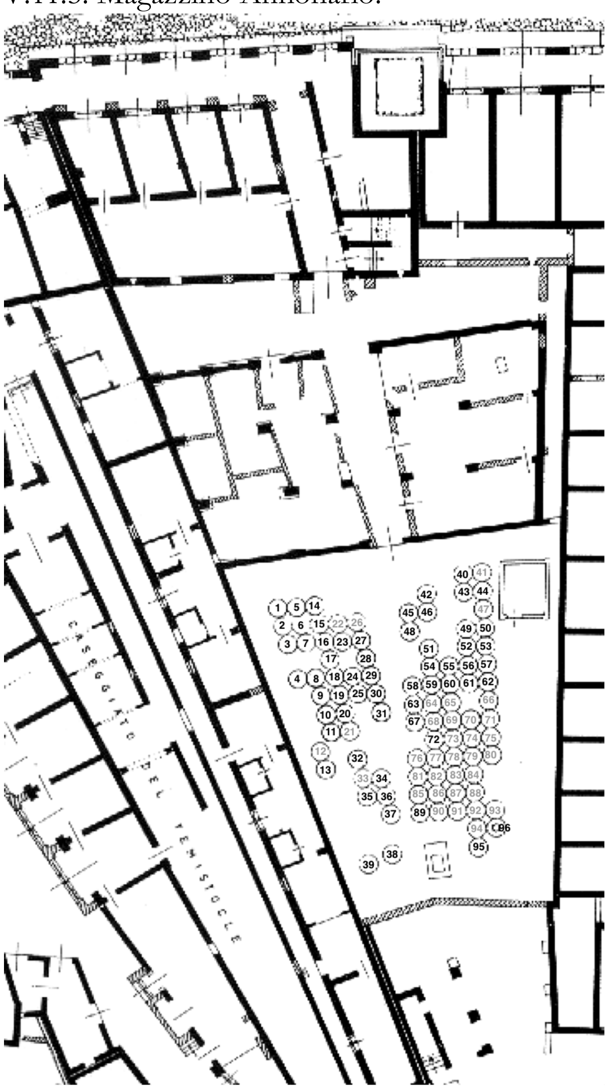
This storeroom was originally connected to the House of Annius, a residence with multiple working areas and a shop. The storeroom was likely constructed with the dolia installed during the first quarter of the second century CE; the dolia were likely not fully buried when originally installed (the ground level has been raised significantly in later periods). On the facade of the house were several terracotta plaques. Three spelled out OMNIA FELICIA ANNI. Two terracotta plaques featured reliefs: one of a man depicted between dolia and the other depicting a boat with dolia. If the owner of this house is the same Annius as Annius Serapiodus, an attested oil-lamp producer of Ostia, it is likely that the dolia of the storeroom contained oil.

III.14.3 no. 1. Large, intact dolium, repaired.
Description: Large, intact dolium almost completely embedded in the ground, filled with soil up to its shoulder. The dolium was repaired.
Dimensions: Exterior rim diameter 83 cm, interior rim diameter 55 cm.

Repairs: Lead double dovetail executed on rim surface in workshop during production-phase, in anticipation of dunting crack that would appear during firing.
Inscription: None.
Stamp: Two stamps placed next to each other on rim upper surface: 1) PYRAMI ENCOLPI/AVG DISP ARCARCI 2) AMPLIATVS VIC F.

III.14.3 no. 6. Large, intact dolium, repaired.
Description: Large, intact dolium almost completely embedded in the ground and contains soil up to its shoulder. The dolium was stamped during production and has repairs.
Dimensions: Exterior rim diameter 87 cm, interior rim diameter 60 cm.
Repairs: One shallow lead alloy fill on interior surface of rim that extends from the rim core to below exposed upper shoulder to repair vertical dunting crack that formed during firing. The repair was probably made in the workshop after firing when the crack emerged.
Stamp: One very faint stamp with text, text illegible now.

V.11.5. Magazzino Annonario.



Large, trapezoidal-shaped storeroom across the decumanus from the theater. This storeroom was excavated hastily in 1939, with only one or two pages of notes recorded in the *Giornale degli Scavi*. The excavations recovered a dolium lid with a stamp (*CIL* 1063?), dating the dolia and warehouse to the first quarter of the second century CE. There were approximately one hundred dolia installed in this storeroom. Every dolium, with the exception of one (no. 67), was broken and is still partly buried, with only part of the middle wall visible today. The storehouse is overgrown, with up to one-third of the dolia inaccessible for study.

D8. Large dolium, broken and repaired.
Description: Large dolium, broken, only part of lower wall visible, with repairs.
Dimensions: wall thickness 5.2 cm; exterior belly diameter 142 cm, interior belly diameter 132 cm.
Repairs: Fills on both interior and exterior walls. Two dark lead alloy vertical fills next to one another on interior wall, likely added in the workshop during production-phase, post-firing. One vertical lead fill on exterior wall, might have been added during use-life or production (regarded as a minor fill compared to the other fills on interior surface).

D52. Large dolium, broken and repaired.
Description: Large dolium, broken, only part of lower wall visible, repaired.
Dimensions: wall thickness 6.7 cm; exterior belly diameter 142 cm, interior belly diameter 129 cm.
Repairs: Lead alloy fill and double dovetail tenon on interior surface. The double dovetail tenon is unusual because it is on the inner wall, and seems as though an additional layer of clay was added to the interior wall, into which the double dovetail was cut. These are likely production-phase repairs.

V.11.5 no. 61. Large dolium, broken and repaired.
Description: Large dolium, broken, only part of lower wall visible, repaired.
Dimensions: wall thickness 4.6 cm; exterior belly diameter 141 cm, interior belly diameter 132 cm.
Repairs: One vertical lead fill on interior surface. Fragment of lead fill (possibly part of double dovetail tenon) on exterior wall, continues below topsoil.

V.11.5 no 67. Large complete dolium, partly buried.
Description: Large complete dolium with major cracks and several repairs.
Dimensions: Exterior rim diameter 88 cm, interior rim diameter 56 cm; preserved height 83 cm; exterior belly diameter 140 cm.
Repairs: Four dark lead alloy fills and a lead alloy 'plug' on exterior surface. Most repairs are in one area. The repairs were likely made in the workshop during the production-phase, post-firing.
Inscription: Two sets of incisions on shoulder of vessel, nearly 180 degrees from each other: XXXVIII ƆIII.

Tables

Chapter 2

Table 2.1. Comparison of different containers discussed in **Chapter 2**.

Container	Material	Purpose(s)	Primary product(s)	Advantages	Disadvantages
Sacks	Linen, hemp, etc.	Short-term packaging	Grain, grapes, olives, other crops.	Widely accessible; lightweight; inexpensive; space-saving; multipurpose.	Can be vulnerable to pests; wear and tear common; limited period and type of use.
Baskets	Rushes, linen, etc.	Short-term transport, processing	Grapes, olives, other crops.	Widely accessible; lightweight; inexpensive; space-saving; multipurpose.	Can be vulnerable to pests; wear and tear common; limited period and type of use.
Skin Containers	Animal hide	Short-term (overland) transport	Wine; olive oil.	Accessible; lightweight; capacious; space-saving; reusable.	Can be vulnerable to pests; wear and tear common; can be cumbersome to transport; cannot be stacked when full.
Amphorae	Ceramic	Distribution, consumption, possible storage	Liquids: wine, olive oil, fish products; fruits. Could be reused as multipurpose jar.	Inexpensive; widely available; disposable but possibly reusable; good for long-term storage and maritime transport.	Ideally for single use; very heavy; somewhat porous so vessel requires conditioning for wine; not easy to transport over land.

Chapter 3 Tables.

Table 3.1. Cosa Dolium and Other Storage Jar Dimensions. Volume in liters, all other dimensions in centimeters.

No.	Other ID	Ext. rim. diam.	Int. rim diam.	Wall thickness	Volume	Height	Depth	Ext. belly diam.	Int. belly diam.	Base diam.
1	CD 707	70	48	5.04	--	--	--	--	--	--
2	CD 708	75	50	4.45	--	--	--	--	--	--
3	C65.124	60	40	3.1	--	--	--	--	--	--
4	C66 V D E.21 S 4, 950433	80	50	--	--	--	--	--	--	--
5	C67.177	70	45	--	--	--	--	--	--	--
6	VIII D II I 15	60	40	4.3	--	--	--	--	--	--
7	CD 47	60	40	--	--	--	--	--	--	--
8	CE 984	--	--	3.2	--	--	--	--	--	37
9	CE 1160	23	15	1.8	--	--	--	--	--	--
10	CE 928	67	43	--	--	--	--	--	--	--
11	C14.100	80	55	--	--	--	--	--	--	--
12	CD 576	33	25	--	--	--	--	--	--	--
13	CE 724	80	50	--	--	--	--	--	--	--
14	NA	24	17	--	--	--	--	--	--	--
15	NA	30	--	--	--	--	--	--	--	--
16	CD 371	85	55	--	--	--	--	--	--	--
17	CD 267	65	45	--	--	--	--	--	--	--
18	CD 266	85	60	--	--	--	--	--	--	--

19	213445	76	50	--	--	--	--	--	--	--
20	Puteal SU 17009	--	--	4.9	--	--	--	--	--	--
21	Puteal SU 17004	--	--	5	--	--	--	--	--	--
22	VIII D 15 III	80	63	--	--	--	--	--	--	--
23	VIII D 24 I 11	75	50	--	--	--	--	--	--	--
24	VIII D 16 IIII	80	55	--	--	--	--	--	--	--
25	Puteal 17009 a	--	--	3.6	--	--	--	--	--	--
26	Puteal 17009 b	--	--	4.6	--	--	--	--	--	--
27	Puteal 17009 c	--	--	3.6	--	--	--	--	--	--
28	Puteal SU 17008	80	--	--	--	--	--	--	--	--
29	C 70 V D SG St. 5	--	--	3.6	--	--	--	--	--	25
30	ANS1-GR 950034	--	25	1.6	--	--	--	--	--	--
31	ANS1-GR 950034	38	30	--	--	--	--	--	--	--
32	C67.353	90	60	--	--	--	--	--	--	--
33	PC72-92	65	40	--	--	--	--	--	--	--
34	Horreum frag.	80	55	--	--	--	--	--	--	--
35	82.8	60	45	--	--	--	--	--	--	--
36	C70 VD SH MGT Garden	60	40	--	--	--	--	--	--	--

37	79	60	45	2.1	--	--	--	--	--	--	--
38	2016 22011	--	--	4.8	--	--	--	--	--	--	--
39	C 70-81	80	65	4.3	--	--	--	--	--	--	--
40	2016 SU 23003	--	--	3.1	--	--	--	--	--	--	--
41	2013 SU 5002	--	--	4.8	--	--	--	--	--	--	--
42	C65.337	80	55	--	--	--	--	--	--	--	--
Avg.		66.2	45.2	3.77	--	--	--	--	--	--	31

Table 3.2. Dolium stamps from Cosa.

Dolium	Stamp Text	Reference	Misc. Info.
Cosa 34, 'horreum'	H (in triangular border)	Unpublished	
Cosa 19, find spot unknown	C· TVRI	Unpublished	
Cosa 42, Temple of Jupiter	L· REMIO· C· F	Bace 1984, 172 D1	

Table 3.3. Pompeii Dolium Dimensions. Volume in liters, all other dimensions in centimeters. For how volume was determined:
A = Ancient inscription of volume on vessel
B = Estimate based on similar vessels with volume determined
C = Calculated with mathematical computation
D = 3D scanning

Property	Dolium no.	Ext. rim diam.	Int. rim diam.	Wall thickness	Volume	Height	Pres. height	Depth	Pres. depth	Ext. belly diam.	Int. belly diam.	Base diam.
I.8.8	12	47	32	--	--	--	--	63	--	--	75	--
I.8.8	13	53	37	--	--	--	--	--	78	--	86	--
I.8.15	1	--	--	3	--	--	--	--	70	82	77	--
I.8.15	2	48	31	--	156[D]	--	--	--	76	--	50	--
I.9.4	3	48	31	--	--	--	--	--	--	--	--	--
I.9.4	4	49	30	--	--	--	--	--	--	--	--	--
I.13.13	1	--	--	1.8	--	--	--	--	--	--	--	--
I.20.1	4	43	28	--	--	--	--	--	--	--	--	--
I.20.5	1	--	--	3.1	--	--	--	--	--	90	--	--
I.20.5	2	62	39	--	--	--	30	--	85	95	--	--
I.20.5	3	64	36	--	--	--	96	--	--	110	--	--
I.20.5	4	--	--	2.6	--	--	--	--	--	90	--	--
I.21.2	1	--	--	3.3	--	--	76	--	76	84	--	--
I.21.2	2	53	31	--	--	--	83	--	83	93	--	--
I.21.2	3	57	37	--	--	--	77	--	77	93	--	--
I.22	1	68	42	--	--	--	90	--	--	90	--	--
I.22	2	--	--	--	--	--	67	--	--	--	--	--
I.22	3	--	--	3.3	--	--	110	--	--	--	--	21

I.22	4	--	--	--	--	--	52	--	--	--	--	20
I.22	5	72	44	3.6	732[C]	132	--	--	--	--	--	21
I.22	6	--	--	4.25	--	--	108	--	--	--	--	--
I.22	7	47	28.5	--	192[C]	94	--			75	69	22
I.22	8	--	37	3	229[C]	86	--	--	--	86	--	18
I.22	9	48.5	29.5	3.5	133[C]	84	--	--	--	77	--	19
I.22	14	--	--	3.1	--	--	--	--	--	--	--	--
I.22	15	--	--	4	--	--	--	--	--	--	--	18
I.22	16	--	--	3.2	--	--	--	--	--	--	--	--
I.22	17	--	--	3.8	--	--	--	--	--	--	--	--
I.22	18	--	--	4	--	--	--	--	--	--	--	--
I.22	19	--	--	3.7	--	--	--	--	--	--	--	--
I.22	20	--	--	3.3	--	--	--	--	--	--	--	--
I.22	21	--	--	3.3	--	--	--	--	--	--	--	--
II.1.8-9	1	50	30	3	--	--	65	--	--	80	--	--
II.5.5	1	61	43	--	550[D]	--	--	105	--	--	120	--
II.5.5	2	--	--	3.6	300[D]	--	--	80	--	--	85	--
II.5.5	3	69	44	--	--	--	--	115	--	--	117	--
II.5.5	4	71	45	--	600[D]	--	--	104	--	--	117	--
II.5.5	5	70	45	--	600[D]	--	--	104	--	--	120	--
II.5.5	6	65	42	--	--	--	--	105	--	--	110	--
II.5.5	7	71	45	--	770[D]	--	--	106	--	--	120	--
II.5.5	8	72	46	4.7	630[D]	--	--	102	--	--	110	--

II.5.5	9	--	--	4.6	300^{D}	--	--	80	--	--	84	--
II.5.5	10	77	49	--	750^{D}	--	--	116	--	--	120	--
II.8.6	1	72	44	--	--	125	--	--	--	117	--	--
II.8.6	2	66	41	--	--	--	90	--	--	90	--	--
II.8.6	3	49	30	--	--	--	--	--	--	80	--	--
V.4.6-7	2	53	38	--	--	--	--	--	--	--	--	--
V.4.6-7	3	64	40	--	--	--	--	--	--	100	--	--
V.4.6-7	5	60	38	--	--	--	--	--	--	100	--	--
VI.9.2	1	64	39	--	--	--	115	--	--	100	--	--
VI.9.10	1	64	40	--	--	--	75	--	--	115	--	--
VI.14.27	1	50	31	--	--	--	--	--	--	--	--	--
VI.14.27	2	44	26.5	--	136^{D}	--	--	--	--	75	--	--
VI.14.27	3	--	--	2.7	--	--	--	--	--	82	--	--
VI.14.27	frag 1	--	--	--	--	--	--	--	--	--	--	--
VI.15.13-15	1	43	28	--	--	--	--	--	--	60	--	--
VI.15.13-15	3	41	26	--	100^{D}	--	--	--	64	--	56	--
VI.15.13-15	5	65	42	--	--	--	--	--	50	--	45	--
VI.15.13-15	frag 1	--	--	--	--	--	--	--	--	--	--	--
VI.15.13-15	frag 2	--	--	3.2	--	--	--	--	--	--	--	--
VI.15.16	2	--	--	--	--	--	--	--	--	--	--	--
VI.14.36	4	44	27	--	--	--	--	--	47	76	66	--
VI.16.40	1	47	27	--	--	--	45	--	67	68	--	--
VII.4.58	1	34	24	--	--	--	--	--	--	55	--	--

VII.5.21	1	78	45	--	--	--	--	--	--	140	--	--
VII.6.15	1	49	32	--	--	--	77	--	--	80	--	--
VII.9.54	1	68	42	3.7	463[D]	--	--	--	93	--	117	--
VII.9.54	2	63	43	--	--	--	--	--	92	--	107	--
VII.9.54	4	--	--	3.5	--	--	--	--	90	--	103	--
VII.13.20	1	46	30	4.1	150[D]	--	--	--	68	--	64	--
VII.16.4	1	46	30	--	--	--	--	--	70	70	--	--
VII.16.4	1	48	32	--	--	--	55	--	65	65	--	--
VII.16.6	1	42	26	--	--	--	66	--	56	62	54	--
VII.16.7	1	39	25	--	--	--	45	--	47	62	51	--
VII.16.7	2	--	--	2.6	--	--	--	--	--	60	54	--
VII.16.7	3	42	26	--	--	--	--	--	--	--	--	--
IX.9.10	1	53	32	3.5	425[B]	--	--	--	80	95	--	--
V Mysteries	1	68	41	--	--	--	--	--	116	110	114	--
V Mysteries	2	--	--	3.8	--	--	--	--	--	110	--	--
V Mysteries	3	73	46	--	--	--	--	--	--	--	--	--
V Mysteries	4	76	48	--	--	--	--	--	--	120	--	--
Unknown	21425	--	--	3.8	--	--	--	--	--	--	--	--
Unknown	47003	80	50	--	--	--	--	--	--	--	--	--
Unknown	?	55	40	--	--	--	--	--	--	--	--	--
Unknown	47004	65	50	--	--	--	--	--	--	--	--	--
Unknown	47006	55	40	--	--	--	--	--	--	--	--	--
Unknown	47005	80	50	--	--	--	--	--	--	--	--	--

Unknown		78	58	--	--	117	--	--	--	115	--	--
V Regina	1	--	43.5	--	695[B]	--	--	--	--	--	--	--
V Regina	2	--	43	--	522[B]	--	--	--	--	--	--	--
V Regina	3	--	43	--	522.4[A]	110	--	--	--	110	--	--
V Regina	4	--	43.5	--	695[B]	--	--	--	--	--	--	--
V Regina	5	--	--	--	522[B]	--	--	--	--	--	--	--
V Regina	6	--	--	--	--	--	--	--	--	--	--	--
V Regina	7	--	42	--	522[B]	--	--	--	--	--	--	--
V Regina	8	--	--	--	--	--	--	--	--	--	--	--
V Regina	9	--	45.5	--	480.8[A]	113	--	--	--	107	--	--
V Regina	10	--	43.5	--	695.3[A]	122	--	--	--	121	--	--
V Regina	11	--	45	--	566.3[A]	122	113	--	--	--	--	--
V Regina	12	--	41.5	--	522.4[A]	111	110	--	--	--	--	--
V Regina	13	--	--	--	--	--	--	--	--	--	--	--
V Regina	14	--	43	--	581.8[A]	118	114	--	--	--	--	--
V Regina	15	--	34	--	392.5[A]	115	100	--	--	--	--	--
V Regina	16	--	44.5	--	712.7[A]	131	122	--	--	--	--	--
V Regina	17	--	44	--	581.5[A]	122	114	--	--	--	--	--
V Regina	18	--	35	--	216.4[A]	91	82	--	--	--	--	--
Lowest value		34	24	1.3	100	84	30	63	47	55	45	18
Mean		58.1	38.1	3.4	478.4	112.1	83.7	98.2	73.8	90	88.5	19.9
Median		57	40	3.5	522.2	116	82.5	104	76	90	85.5	20
Highest value		80	58	4.7	770	132	122	116	116	140	120	22

Table 3.4. Dolium Stamps from Pompeii.

Property	Stamp Text	Reference	Misc. Info.
VII 15 15	ANTEROTIS *litt. cavis pulchr.* GALLICI	*CIL* X 8047, 2	
VI 8 9	(*anulo impressa*) A· APPVLEI (*anulo impressa*) (*uva vel folium*) HILARIONIS (*uva vel folium*) FIRMVS· FEC	*CIL* X 8047, 3	Also found on dolium at Villa B in Gragnano; also found at Stabiae
Unknown	(*anulo impressa*) A· APPVLEI (*anulo impressa*) (*uva vel folium*) HILARIONIS (*uva vel folium*)	*CIL* X 8047, 3	In Naples Museum
VII 4 11	(*anulo impressum pomnum*) A· APPVLEI/QVIETI (*anulo impressum pomnum*) *litteris cavis*	*CIL* X 8047, 4	Also found at Stabiae
VII 12 9	ASCL· PONTI *Ascl(epiadis) Ponti.*	*CIL* X 8047, 5	*CIL* X 8042 76: Q MCI ASLEPIAD appears on at least seven tiles
VII 7 19	(*caduceus altus*) D· F· C· CLVENTI/ AMPLIATI (*caduceus altus*) (*palmae a ramus insertus coronae; supra luna crescens*) CORINTHVS· S· F (*palmae a ramus insertus coronae; supra luna crescens*) *D(e?) f(gilinis?) C. Cluenti Ampliati. Corinthus s(ervus) f(ecit)*	*CIL* X 8047, 7	
I 3 2	(*ramus palmae*) C· CLVENTI/AMPLIATI (*ramus*	*CIL* X 8047, 6	Also found *a ziro di mattone* at

	palmae) *litteris cavis pulchris*		Pompeii and on four ceramic vases
I 3 20 VI 14 36 Two dolia of unknown provenience	(*sigillum vaccum*) L· CORNELI RUFION (*sigillum vaccum*)	*CIL* X 8047, 8	Four dolia.
IX 5 11	PHILEROS M· FULVI· SER	*CIL* X 8047, 15	Phileros appears on a stamp in Rome
VI 8 8	LAVRINI PINNIAES	*CIL* X 8047, 9	On two dolia, both of which have incised Roman numerals for capacities: Ↄ · XVI ↃXIX · P· C//
VII 4 11, VII 4 14	(*anulo impressum: folium uvae*) M· LVCCEI QVARTIONIS (*anulo impressum: folium uvae*) *litt. cavis pulchris*	*CIL* X 8047, 10 a	Incised with Roman numeral for capacity: XLIII.
VII 4 11, VII 4 14	(*anulo impressum: guttus*) M· LVCCEI QVARTIONIS (*anulo impressum: guttus*) *litt. cavis pulchr.*	*CIL* X 8047, 10 b-c	Two dolia, one incised with Roman numerals for capacity: XLVI.
VI 14 36	M· LVCCEI *litt. cavis pulchr.* QVARTIONSI *sic* AVKIOY (*litt. cavis*)	*CIL* X 8047, 10 d	
NA	C· N· V C· NA*evi vital*IS C· N	*CIL* X 8047, 11a	Also produced tiles, *CIL* X 8042

			81. C· N· V C· N· V/C· NAEVI VITALIS C· N· V
VII 2 48	*sigillum: folium?* (*idem sigillum*) C· NAEVI VITALIS (*idem sigillum*) *litt. cavis pulchr.*	*CIL* X 8047, 11b	Also produced tiles, *CIL* X 8042 81. C· NAEVI VITALIS
NA	SEX· OBINI· SALVI (*litt. cavis*)	*CIL* X 8047, 12	Also found at Castellammare di Stabiae
VII 4 11 and VII 4 14	M· PACCI· HILARI (*litt. cavis*) (*anulo impressum: vasculum*)	*CIL* X 8047 13	Also found at Castellammare di Stabiae
I I 2	M· PACCI SEC (*litt. cavis*)	*CIL* X 8047 14	
VII 2 48	(*sigillum detritum*) L· SAGINI (*sigillum detritum*)	*CIL* X 8047, 16	Also produced tiles, *CIL* X 8042 90. L· SAGINI; L· SAGINI PRODMI appears on many tiles, *CIL* X 8042 91.
VII 7 21	C SATRINI COMMUNIS MARCIAN *sic*	*CIL* X 8047, 17	Also produced 'urban' tiles, *CIL* X 8042 93. C· SATRINI/COMMUNIS MARCIAN *sic*
VII 4 11 VII 4 14	L· TITI· T· F· PAP	*CIL* X 8047, 18	On at least three dolia; one with post-cocturum incision 'P CXI', one with post-cocturum incision 'P CI'.

VII 4 56	(*sigillum: vasculum?*) M· VIBI LIBERALIS (*idem sigillum*)	*CIL* X 8047, 19 a-b	On two dolia.
VI 2 5	M· VIBI LIBERALIS (*sigillum: folium*) (*litt. cavis*)	*CIL* X 8047, 19c	
VII 2 32/3 VII 3 3	MV· A· P (*litteris pulchris*)	*CIL* X 8047, 1 a-b	On two dolia.
I 2 1	MVA////// ////////// *litt. cavis pulchr.*	*CIL* X 8047, 1c	
IX 1 3	(*sigillum incertum*) VITALIS GALLICI (*sigillum incertum*) (*litt. cavis*)	*CIL* X 8047, 20	
IX 2 7	L////VORVM LVCC///V· S	*CIL* X 8047, 21	
I 5 5	EROTICV[	Unpublished?	
I 5 5	]..MICVI…	Unpublished?	
Dolium lid, inv. no. 17464	A· PLAVTI EVTACTI	Unpublished?	Also on lid of a dolium from Gragnano "Contrada Messigno", Della Corte 1923, 274 and 'APE' on dolium lid at Gragnagno "Contrada Carita" and another villa at Gragnano, Della Corte 1932, 278.

Table 3.5. Ostia Dolium Dimensions. Volume is in liters and all other dimensions are in centimeters. Volume determined by ancient incisions in unit of amphorae.

Property	Dolium no.	Ext. rim diam.	Int. rim diam.	Wall thickness	Volume	Height	Pres. height	Depth	Pres. depth	Ext. belly diam.	Int. belly diam.	Base diam.
I.4.5	1	104	73	--	1102.04	--	--	--	--	130	--	--
I.4.5	2	99	64	--	1061.1	--	--	--	--	130	--	--
I.4.5	3	--	--	5.5	--	--	--	--	--	133	--	--
I.4.5	4	--	--	5.5	1010.34	--	--	--	--	134	--	--
I.4.5	5	--	--	5.8	--	--	--	--	--	130	--	--
I.4.5	6	--	--	4.4	--	--	--	--	--	130	--	--
I.4.5	7	--	--	--	--	--	--	--	--	140	--	--
I.4.5	8	--	--	6.0	--	--	--	--	--	135	--	--
I.4.5	9	--	--	5.2	--	--	--	--	--	135	--	--
I.4.5	10	--	--	4.8	746.7 or 1008.7	--	--	--	--	135	--	--
I.4.5	11	--	--	--	1231.4	--	--	--	--	140	--	--
I.4.5	12	99	67	--	1101.49	--	--	--	--	145	--	--
I.4.5	13	--	--	4.0	--	--	--	--	--	130	--	--
I.4.5	14	--	--	5.3	--	--	--	--	--	137	--	--
I.4.5	15	--	--	5.1	--	--	--	--	--	132	--	--
I.4.5	16	104	70	--	1061.1	--	--	--	--	130	--	--
I.4.5	17	96	63	--	1100.4	--	--	--	--	134	--	--
I.4.5	18	--	--	4.8	--	--	--	--	--	125	--	--
I.4.5	19	--	--	--	957.39	--	--	--	--	135	--	--
I.4.5	20	--	--	--	1036	--	--	--	--	133	--	--

I.4.5	21	--	--	5.1	--	--	--	--	--	127	--	--	--
I.4.5	22	--	--	--	877.7	--	--	--	--	128	--	--	--
I.4.5	23	--	--	4.8	1061.1	--	--	--	--	123	--	--	--
I.4.5	24	--	--	4.5	930.1	--	--	--	--	120	--	--	--
I.4.5	25	--	--	4.9	1139.7	--	--	--	--	136	--	--	--
I.4.5	26	--	--	--	1036	--	--	--	--	125	--	--	--
I.4.5	27	--	--	--	851.5	--	--	--	--	110	--	--	--
I.4.5	28	--	--	--	774	--	--	--	--	110	--	--	--
I.4.5	29	96	65	--	1074.2	--	--	--	--	118	--	--	--
I.4.5	30	--	--	5.0	1126.6	--	--	--	--	130	--	--	--
I.4.5	31	--	--	4.5	1139.7	--	--	--	--	135	--	--	--
I.4.5	32	101	66	--	1113.5	--	--	--	--	130	--	--	--
I.4.5	33	100	64	--	--	--	--	--	--	--	--	--	--
I.4.5	34	102	71	--	1036.5	--	--	--	--	135	--	--	--
I.4.5	35	--	--	4.1	--	--	--	--	--	125	--	--	--
I.4.5	36	102	72	--	1087.3	--	--	--	--	130	--	--	--
III.14.3	1	83	55	--	--	--	--	--	--	--	--	--	--
III.14.3	2	99	71.5	--	--	--	--	--	--	--	--	--	--
III.14.3	3	93.5	64	--	--	--	--	--	--	--	--	--	--
III.14.3	4	--	66	--	--	--	--	--	--	--	--	--	--
III.14.3	5	93	62.5	--	--	--	--	--	--	--	--	--	--
III.14.3	6	87	60	--	--	--	--	--	--	--	--	--	--
III.14.3	7	85	58	--	--	--	--	--	--	--	--	--	--

III.14.3	8	80	57	--	--	--	--	--	--	--	--	--
III.14.3	9	90	60	--	--	--	--	--	--	--	--	--
III.14.3	10	83	55	--	--	--	--	--	--	--	--	--
III.14.3	11	78	51	--	--	--	--	--	--	--	--	--
III.14.3	12	85	57	--	--	--	--	--	--	--	--	--
III.14.3	13	81	53.5	--	--	--	--	--	--	--	--	--
III.14.3	14	--	--	--	--	--	--	--	--	--	--	--
III.14.3	15	--	--	--	--	--	--	--	--	--	--	--
III.14.3	16	85	59	--	--	--	--	--	--	--	--	--
III.14.3	17	73	47	--	--	--	--	--	--	--	--	--
III.14.3	18	87	60	--	--	--	--	--	--	--	--	--
III.14.3	19	--	--	--	--	--	--	--	--	--	--	--
III.14.3	20	93	66	--	--	--	--	--	--	--	--	--
V.6.5	1	--	--	3.9	--	--	--	--	--	124	117	--
V.6.5	2	--	--	5.6	--	--	--	--	--	133	125	--
V.6.5	3	--	--	5.1	--	--	--	--	--	136	124	--
V.6.5	4	--	--	5.3	--	--	--	--	--	131	122	--
V.6.5	5	--	--	4.7	--	--	--	--	--	140	127	--
V.6.5	6	--	--	5.0	--	--	--	--	--	146	139	--
V.6.5	7	--	--	5.3	--	--	--	--	--	137	125	--
V.6.5	8	--	--	5.3	--	--	--	--	--	142	132	--
V.6.5	9	--	--	4.4	--	--	--	--	--	140	132	--
V.6.5	10	--	--	5.2	--	--	--	--	--	121	110	--

V.6.5	11	--	--	5.6	--	--	--	--	--	125	117	--
V.6.5	12	--	--	5.4	--	--	--	--	--	116	105	--
V.6.5	13	--	--	4.3	--	--	--	--	--	123	116	--
V.6.5	14	--	--	4.7	--	--	--	--	--	134	127	--
V.6.5	15	--	--	4.7	--	--	--	--	--	138	122	--
V.6.5	16	--	--	4.5	--	--	--	--	--	139	129	--
V.6.5	17	--	--	4.5	--	--	--	--	--	136	126	--
V.6.5	18	--	--	4.1	--	--	--	--	--	128	120	--
V.6.5	19	--	--	4.9	--	--	--	--	--	125	116	--
V.6.5	22	--	--	4.9	--	--	--	--	--	131	124	--
V.6.5	23	--	--	4.9	--	--	--	--	--	137	128	--
V.6.5	24	--	--	4.8	--	--	--	--	--	130	120	--
V.6.5	26	--	--	--	--	--	--	--	--	--	--	--
V.6.5	27	--	--	4.8	--	--	--	--	--	129	120	--
V.6.5	28	--	--	4.8	--	--	--	--	--	124.5	115	--
V.6.5	29	--	--	4.4	--	--	--	--	--	129	118	--
V.6.5	30	--	--	4.6	--	--	--	--	--	115	124	--
V.6.5	31	--	--	4.8	--	--	--	--	--	121	113	--
V.6.5	32	--	--	4.8	--	--	--	--	--	127	119	--
V.6.5	33	--	--	5.0	--	--	--	--	--	138	128.5	--
V.6.5	34	--	--	5.1	--	--	--	--	--	137	130	--
V.6.5	35	--	--	4.4	--	--	--	--	--	--	--	--
V.6.5	36	--	--	5.2	--	--	--	--	--	136	131	--

V.6.5	37	--	--	4.2	--	--	--	--	--	128	118	--
V.6.5	38	--	--	4.2	--	--	--	--	--	--	--	--
V.6.5	39	--	--	4.6	--	--	--	--	--	135	124	--
V.6.5	40	--	--	4.2	--	--	--	--	--	--	--	--
V.6.5	41	--	--	--	--	--	--	--	--	--	--	--
V.6.5	42	--	--	5.0	--	--	--	--	--	139	130	--
V.6.5	43	--	--	4.6	--	--	--	--	--	135	126	--
V.6.5	44	--	--	4.1	--	--	--	--	--	122	114	--
V.6.5	45	--	--	5.0	--	--	--	--	--	123	113	--
V.6.5	46	--	--	4.1	--	--	--	--	--	134	128	--
V.6.5	47	--	--	4.9	--	--	--	--	--	136	125	--
V.6.5	48	--	--	3.0	--	--	--	--	--	129	123	--
V.6.5	49	--	--	4.8	--	--	--	--	--	121.5	113	--
V.6.5	50	--	--	4.7	--	--	--	--	--	144	136	--
V.6.5	51	--	--	4.6	--	--	--	--	--	129	122	--
V.6.5	52	--	--	6.7	--	--	--	--	--	142	129	--
V.6.5	53	--	--	5.2	--	--	--	--	--	140	133	--
V.6.5	54	--	--	4.7	--	--	--	--	--	141	132	--
V.6.5	55	--	--	5.0	--	--	--	--	--	134	125	--
V.6.5	56	--	--	4.9	--	--	--	--	--	132	122	--
V.6.5	57	--	--	4.7	--	--	--	--	--	132	122	--
V.6.5	58	--	--	5.0	--	--	--	--	--	136	127	--
V.6.5	59	--	--	5.3	--	--	--	--	--	140	129	--

V.6.5	60	--	--	6.4	--	--	--	--	--	137	126	--
V.6.5	61	--	--	4.6	--	--	--	--	--	141	132	--
V.6.5	62	--	--	4.6	--	--	--	--	--	109	100	--
V.6.5	63	--	--	4.3	--	--	--	--	--	--	--	--
V.6.5	64	--	--	4.3	--	--	--	--	--	--	--	--
V.6.5	65	--	--	4.9	--	--	--	--	--	--	--	--
V.6.5	66	--	--	4.1	--	--	--	--	--	--	--	--
V.6.5	67	88	56	--	997.24	--	83	--	--	140	--	--
V.6.5	68	--	--	--	--	--	--	--	--	--	--	--
V.6.5	BF1	--	--	--	--	--	--	--	--	--	--	--
V.6.5	BF2	--	--	--	--	--	--	--	--	--	--	--
V.6.5	BF3	--	--	--	--	--	--	--	--	--	--	--
V.6.5	BF4	--	--	--	--	--	--	--	--	--	--	--
Lowest Value		73	47	3.0	774	--	83	--	--	109	100	--
Mean		91.6	61.9	4.88	1016.3 or 1027.2	--	83	--	--	131.4	123.2	--
Median		93	63	4.8	1061.1	--	83	--	--	132.5	124	--
Highest Value		104	73	6.4	1139.7	--	83	--	--	146	136	--

Table 3.6. Dolium Stamps from Ostia.

Property	Stamp Text	Reference	Notes
III 14 3	*cornucopiae* L· AVTRONI XANTHI *bipennis*	Bloch 1948, 96 n. 470	
III 14 3, no. 12	*bucranium* L· C[A]ECILIVS PROCLVS *signum detritum*	Bloch 1948, 96 n. 471	
cella prope thermas adhuc extantibus	M [F]VRI· VINDICIS *alterum sigillum in labro eiusdem dolii impressum praeter ornamenta totum evanuit*	*CIL* XV 2447a = *CIL* XIV 4093, 12	
nel fondo la Torretta	M· FVRI VINDICIS	*CIL* XV 2447b	Information from catalog, dolium said no longer to exist
I 4 5	GENIALIS RASINI PONTICI SER FE	Gatti 1903, p. 202	Same stamp found on dolium from Rome, *CIL* XV 2449
III 14 3, no. 6	*bucranium* C IVLI RVFI *bucranium* L· ARISTAEVS RESTITVTVS **FF** *caput bovis caput bovis caput bovis caput bovis*	Bloch 1948, 101 n. 509	
Ostia Museum	L· LVRIVS *ramus palmae* VERECVN FE *L. Lurius Verecun(dus) fe(cit)*	*CIL* XV 2459	
cella prope thermas adhuc extantibus	Q· OCI/////	*CIL* XV 2475	Stamped on rims of two dolia?

cella prope thermas adhuc extantibus	*ramus palmae* *corona* FAVSTVS· FEc *oron* *corona* L· PETRONI FVSCI FECIT FAVSTVS· SER *corona* *ramus palmae*	*CIL* XV 2479 = *CIL* XIV 4093, 3	Two separate stamps.
III 14 3, no. 1	PYRAMI ENCOLPI AVG DISP· ARCARI AMPLIATVS· VIC· F *Pyrami, Encolpi Aug(usti) disp(ensatoris) arcari; Ampliatus vic(arius) f(ecit)*	Bloch 1948, n. 537	Pyramus could have been T. Flavius Pyramus in Bloch 1948, n. 506: T· FLAVI· PYRAMI ADIVTOR· SER· FEC, on dolium in Rome.[420]
Ostia surroundings	*ramus palmae* L RVFEN· PROCVLI LEO· SER· FEC *caduceus* *ramus palmae* *L. Rufen(i) Proculi; Leo ser(vus) fec(it)*	*CIL* XV 2488 = *CIL* XIV 4093.6; Lanciani 1885a, p. 77	Another slave from same estate appears on a dolium in Rome, *CIL* XV 2487: L· RVFENI· PROCVL/COGIT*a*TVS· SER· F
III 14 3	*caput bovis caput bovis caput bovis* II· RVFENORVM CELERIS ET POLLIO	Bloch 1948, 106 n. 539	

[420] Bloch 1948, 106 n. 537: "Pyramus was the *arcarius* of the imperial *dipensator* Encolpus, Ampliatus his *vicarius*. An *Aug(usti) disp(ensator) arcar(ius) regn(i) Noric(i)* occurs in *ILS* 1506 (Virunum = Klagenfurt); an *Aug(ustorum) n(ostrum) dispensatoris arkarius* in *ILS* 1661 (Caesarea, Cappadocia); a *dispensatoris fisci castrenis arcarius* in *ILS* 1660 from Rome (cf. O. Hirschfeld, *Kaiserl. Verwaltungsbeamte*^{2}, 401 n. 3 and 461 n. 3). Encolpus may have been connected with the *annona*."

	(Duorum) Rufenorum Celeris et Pollio(nis)		
cella prope thermas adhuc extantibus	C· TITIENI C F FLORI *caput bovis infulatum* REPENTINVS F *caput bovis infulatum*	*CIL* XV 2500a = XIV 4093, 7	Two separate stamps on same dolium; identical set on dolium found on Equiline in Rome, *CIL* XV 2500b.
cella prope thermas adhuc extantibus	*thyrsus vittis exornatus* *caput bovis* *caput bovis* Q· TOSSIVS· PROCVLVS· F *caput bovis* *caput bovis* *caput bovis* *ramus palmae*	*CIL* XV 2507	Different members of the Tossius family appear on many *opus doliare* products from the late Republic period onwards, typically in southern Etruria and northern Latium.[421]
III 14 3	*caput bovis* C VIBI FORTVNATI C VIBI CRESCENTIS *caput bovis*	Bloch 1948, 111 n. 565	Bloch: "C. Vibius Crescens was undoubtedly a slave of Vibius Donatus before his manumission."
III 14 3	*caput bovis* C· VIBIVṢ *caput bovis* F̣ORTVNẠṬ FEC.	Bloch 1948, 111 n. 564	Bloch: "C. Vibius Fortunatus is the *Fortunatus ser(vus)* of 2512 after his manumission by C. Vibius Donatus. Cf. **563**."
I 4 5	RHODINVS SER· FEC	Bloch 1948, 106 n. 538	

421 Taglietti 2015 discusses the activities and chronology of the Tossius family. Carrato 2017, 619 includes a dolium in Gaul with stamp of Q. Tossius Priscus, who has been attested on dolia in Rome.

Chapter 4

Table 4.1. Overview of repairs on dolia at Cosa.

Vessel	Production Phase	Use	Unknown Stage
Cosa no. TC	-- -- -- -- --	Clamp	-- -- -- -- --
Cosa no. 19	-- -- -- -- --	Hybrid Mortise and tenon Clamp; hybrid mortise and tenon double dovetail	-- -- -- -- --
Cosa no. 29	-- -- -- -- --	Hybrid mortise and tenon double dovetail	-- -- -- -- --
Cosa no. 11	-- -- -- -- --	Clamp?	Double dovetail
Cosa no. 1	-- -- -- -- --	Clamp?	-- -- -- -- --

Table 4.2. Overview of repairs on storage vessels at Pompeii.

	Dolia			Cylindrical Jars		
	Count	% of repaired spherical dolia	% of all Repaired	Count	% of repaired cylindrical jars	% of all repaired
Repaired	30	----	73.2%	11	---	26.8%
Production	21	70%	51.2%	4	36.4%	9.8%
Use	7	23.3%	17.1%	3	27.3%	7.3%
Production and Use	4	13.3%	9.8%	1	9.1%	2.4%
Lead	18	60%	43.9%	4	36.4%	9.8%
Lead Alloy	6	20%	14.6%	0	0	0
Fill(s)	3	10%	7.3%	3	27.3%	7.3%
Staple(s)	4	13.3%	9.8%	2	18.2%	4.8%
Clamp(s)	11	36.7%	26.8%	5	45.5%	12.2%
Hybrid	5	16.7%	12.2%	0	0	0
Double Dovetail	16	53.3%	39.0%	4	36.4%	9.8%
Double Dovetail Tenon	14	46.7%	34.1%	0	0	0
One Technique	17	56.7%	41.5%	8	72.7%	19.5%
Two+ Techniques	13	43.3%	31.7%	3	27.3%	7.3%

Table 4.3. Repair types, materials, and stages on Pompeian dolia and cylindrical storage jars. Metal material noted when preserved.

Vessel	Production Phase	Use-Life	Unknown Stage
I.22 n. 2	-- -- -- -- -- -- -- -- -- -- -- --	-- -- -- -- -- -- -- -- -- -- -- -- -	Lead fill
I.22 n.3	Lead alloy double dovetails and double dovetail tenons	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n.5	Double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n. 6	Lead alloy double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n. 7	-- -- -- -- -- -- -- -- -- -- -- --	Lead fill; hybrid double dovetail tenon staple (unknown material)	-- -- -- -- -- -- -- --
I.22 n. 14	Double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n. 17	Double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n. 18	Lead clamp	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.22 n. 19	-- -- -- -- -- -- -- -- -- -- -- --	Clamp	-- -- -- -- -- -- --
I.22 n. 20	Double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.8.8 n. 13	Lead double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.21.2 n. 1	Lead alloy double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
I.21.2 n. 2	-- -- -- -- -- -- -- -- -- -- -- --	Lead staple and clamp	-- -- -- -- -- -- --
II.8.6 n. 1	Lead alloy double dovetail and hybrid double dovetail tenon clamp	Lead clamps	
II.8.6 n. 2	Lead double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
VII.5.21 n. 1	Lead alloy double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
II.1.8-9 n. 1	-- -- -- -- -- -- -- -- -- -- -- --	-- -- -- -- -- -- -- -- -- -- -- -- -	Lead staple and clamp

VI.15.13 n. 5	Clamp	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
VI.14.2 f. 1	Clamp	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
VII.4.58 n. 1	-- -- -- -- -- -- -- -- -- -- -- --	Lead double dovetail	-- -- -- -- -- -- --
II.5.5 n. 1	Lead double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	Lead clamp
II.5.5 n. 4	Double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
II.5.5, n. 5	Lead double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
II.5.5 n. 8	Double dovetail tenon	Lead hybrid staple mortise-and-tenon	Lead clamp
II.5.5 n. 9	Lead clamp	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
II.5.5 n. 10	Lead double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	Lead Fill
VM n. 2	Lead double dovetail	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
VM n. 3	Lead double dovetail and double dovetail tenon	Lead hybrid double dovetail staple	-- -- -- -- -- -- --
VM n. 4	Lead double dovetail and double dovetail tenon	-- -- -- -- -- -- -- -- -- -- -- -- -	-- -- -- -- -- -- --
VI.16.40 n. 1	-- -- -- -- -- -- -- -- -- -- -- --	-- -- -- -- -- -- -- -- -- -- -- -- -	Lead clamp

Table 4.4. Overview of dolium repairs at Ostia.

Repairs on Ostian Dolia	**Total (124)**	**Repaired (50)**
Type of Repair = raw quantity of dolia	Out of Total	Out of Repaired
Number of Repaired Dolia = 50	40.3%	(100%)
Dolia Repaired with lead = 32	25.8%	64%
Dolia Repaired with lead alloy = 19	15.3%	38%
Dolia Repaired with lead and lead alloy = 9	7.3%	18%
Dolia Repaired with one technique = 40	28.2%	80%
Dolia Repaired with two techniques = 8	10.5%	16%
Dolia Repaired During Production Phase, With Certainty = 24	19.4%	48%
Fills on Interior Surface = 18	14.4%	36%
Lead Fills on Interior Surface made in Lead = 13	10.5%	26%
Lead Alloy Fills on Interior Surface = 2	1.6%	4%
Lead and Lead Alloy Fills on Interior Surface = 1	0.8%	2%
Fills on Exterior Surface = 16	12.9%	32%
Lead Fills on Exterior Surface = 9	7.3%	18%
Lead Alloy Fills on Exterior Surface = 3	2.4%	6%
Double dovetail on Exterior Surface = 9	7.3%	18%
Lead Double Dovetail on Exterior Surface = 6	4.8%	12%
Lead Alloy Double Dovetail on Exterior Surface = 1	0.8%	2%
Lead & Lead Alloy Double Dovetails on Exterior Surface = 1	0.8%	2%
Lead Alloy Double Dovetail Tenon on Interior Surface = 1	0.8%	2%
Double Dovetail Tenon on Exterior Surface = 21	16.9%	42%
Lead Double Dovetail Tenon on Exterior Surface = 6	4.8%	12%
Lead Alloy Double Dovetail Tenon on Exterior Surface = 8	6.5%	16%
Lead & Lead Alloy Double Dovetail Tenon, Exterior Surface = 1	0.8%	2%

Table 4.5. Dolium Repairs at Ostia. Metal noted when preserved; lead alloy considered a *production* repair material; lead grouped in unknown stage except when dolium also has lead alloy filler repairs.

Vessel	Production Phase	Use-Life	Unknown Stage
I.4.5 n. 1	Lead double dovetail	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 2	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead Fill
I.4.5 n. 3	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead Fill
I.4.5 n. 5	Double dovetail	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 6	Double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 11	Lead alloy double dovetail tenon; fill	-- -- -- --	Lead Fill (probably use)
I.4.5. n. 12	Lead alloy double dovetail tenon; double dovetail	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 17	Lead alloy double dovetail tenon	-- -- -- --	Fill
I.4.5 n. 23	Double dovetail	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 26	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Fill
I.4.5 n. 27	Double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 28	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 30	Lead alloy double dovetail; double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 34	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
I.4.5 n. 35	Lead alloy double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
I.4.5 n. 36	Double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --
III.14.3 1	Lead double dovetail	-- -- -- --	Lead fill
III.14.3 6	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
V.6.5 n. 2	Lead alloy double dovetail tenon	-- -- -- --	Lead fill
V.6.5 n. 3	Lead alloy fill	-- -- -- --	-- -- -- -- -- -- -- --
V.6.5 n. 4	-- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Fill
V.6.5 n. 5	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- --

V.6.5 n. 6	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Fill
V.6.5 n. 7	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 8	Lead alloy fill	Lead fill	-- -- -- -- -- -- -- -- --
V.6.5 n. 17	Lead alloy double dovetail tenon	-- -- -- --	Lead fill
V.6.5 n. 22	Double dovetail tenon	-- -- -- --	Lead fill
V.6.5 n. 26	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 32	Lead alloy double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 37	Lead and lead alloy double dovetails	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 42	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 46	Double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 47	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
V.6.5 n. 48	Double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 52	Lead alloy fill	Lead fill	-- -- -- -- -- -- -- -- --
V.6.5 n. 53	Lead and lead alloy double dovetail tenons	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 54	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fills
V.6.5 n. 56	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead alloy double dovetail tenon; lead fill
V.6.5 n. 58	Lead alloy fill	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 59	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
V.6.5 n. 61	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
V.6.5 n. 62	Lead double dovetail tenon	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 64	Lead double dovetail	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 65	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill
V.6.5 n. 67	Lead alloy fill	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 n. 68	Lead double dovetail	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 BF 1	-- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill

V.6.5 BF 2	Lead double dovetail	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 BF 3	Lead double dovetail	-- -- -- --	-- -- -- -- -- -- -- -- --
V.6.5 BF 4	-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --	-- -- -- --	Lead fill

Table 4.6. Possible repairers of dolium repair types, according to stage of execution.

Repair	Stage(s)	Tools, Equipment	Location	Possible Repairer(s)
Fills	Production	Lead and open flame; lead and other metal (for lead alloy) and furnace. Tool for applying metal into crack.	Dolium Production Site	a) member of the dolium production site: dolium maker, specialist repairer b) outsider: specialist repairer, another craftsperson, metal worker (especially for lead alloys)
	Use	Lead and open flame. Tool for applying metal into crack.	Place of use: farm, shop, warehouse	a) user of vessel: member of farm, shop, or warehouse b) outsider: tinker, specialist craftsperson, metallurgist
Lead or Lead Alloy Staples or Clamps	Production	Lead and open flame; lead and other metal (for lead alloy) and furnace. Drill.	Dolium Production Site	a) member of the dolium production site: dolium maker, specialist repairperson b) outsider: specialist repairperson, another craftsperson, metal worker (especially for lead alloys)
Lead Staples or Clamps	Use	Lead, open flame, mold for cross piece, drill.	Place of use: farm, shop, warehouse	a) user of vessel: member of farm, shop, or warehouse b) outsider: pottery mender, specialist craftsperson, tinker, metal worker
Iron and Lead Staples or Clamps	Use	Iron pins and crosspieces, lead, open flame, tool for applying metal, drill.	Place of use: farm, shop, warehouse	a) user of vessel: b) outsider: tinker, metalworker, architectural craftsperson
Double Dovetail or Double Dovetail Tenons	Production	Lead and open flame; lead and other metal (for lead alloy) and furnace. Tools for cutting mortises and applying and securing metal tenon into mortises.	Dolium Production Site	a) member of the dolium production site: dolium maker, specialist repairer b) outsider: architectural craftsperson, specialist repairperson, another craftsperson, metal worker (especially for lead alloys)
Hybrid (Staple or Clamp + Mortise-and-Tenon)	Use	Lead and open flame. Drill. Tools for cutting mortises and applying and securing metal tenon.	Place of use: farm, shop, warehouse	a) user of vessel b) outsider: architectural craftsperson, pottery mender, tinker, specialist repairer

Table 4.7. Possible repairers of different types of dolium repairs, according to metal material.
* It is uncertain whether lead alloy could be and was used during use-life.

Metal(s)	Phase	Possible Repairer
Lead	Production	Member of dolium workshop, metal worker
Lead	Use	Metal worker, tinker, specialist craftsperson, pottery mender
Lead Alloy	Production	Member of dolium workshop, architectural craftsperson, metal worker
Lead Alloy	*Use**	*Metal Worker*
Iron and Lead	Use	Architectural craftsperson, metal worker, specialist craftsperson

Table 4.8. Comparison of different types of dolium repairs, their materials, stage of execution, how often they appear on other types of pottery, and where they occur.

Repair Technique	Phase	Material(s)	On Pottery	Sites
Fill	Production and/or use	Lead, lead alloy	Rare	Ostia, Pompeii
Staple	Production and/or use	Lead	Common	Pompeii
Clamp	Production and/or use	Lead	Common	Pompeii, Cosa
Hybrid MTS	Use	Lead	Rare	Pompeii
Hybrid MTC	Use	Lead	Rare	Cosa
Hybrid MTDD	Use	Lead	Rare	Cosa, Pompeii
Double dovetail	Production (ideally)	Lead, lead alloy	Rare	Ostia, Pompeii, Cosa
Double dovetail tenon	Production (ideally)	Lead, lead alloy	None	Ostia, Pompeii

Chapter 5

Table 5.1. Dolium vessel capacity volume (how much a dolium could hold), vessel clay volume (how much clay was used for form the dolium), and the dolium's estimated weight. Calculated vessel volumes and clay volumes based on calculations by Stanley Chang from profile drawings Gina Tibbott generated or was based on an ancient capacity incision. Gina Tibbott generated 3-D models of several dolia in the application SketchUp, which she then used to estimate the vessel's capacity volume and clay volume. Some of the figures differ from what was generated from the SketchUp models, and hence have been included here for comparison. The clay volumes are multiplied with a density figure (1920 kg/m^3) for ceramic paste similar to dolia's to estimate the weight of the vessel.

Dolium	Calculated Vessel Volume (l)	Calculated Clay volume (l)	Estimated Weight (kg)	SketchUp Vessel volume (l)	SketchUp Clay volume (l)	Estimated weight (kg)
I.22 no. 7	192	527.6	101.2	200.5	629.1	120.8
I.22 no. 9	133	509.4	97.8	170.3	683.9	131.3
I.22 no. 10	134	597.6	114.7	167.5	808.1	155.2
I.22 no. 11	135	878.7	168.7	164.9	947.5	181.9
I.22 no. 12	136	1,066.6	204.8	161.2	1081.7	207.7
I.22 no. 13	137	1,207.0	231.7	164.6	1188.1	228.1
I.22 no. 14	138	1,370.0	263.0	157.8	1343.9	258.0
Boscoreale Antiquario	--	2,689.1	516.3	386.4	3430.9	658.7
I.22 no. 1	--	2,479.2	476.1	217.4	2216.3	425.5
I.22 no. 8	229	602.6	115.7	228.0	745.7	143.2
VRB no. 3	522,41	1,868.4	358.7	320.2	2976.6	571.5
VRB no. 10	695,33	2,742.8	526.6	433.4	3665.0	703.7
VRB no. 9	480,82	2,304.1	442.4	289.3	3178.7	610.3
I.22 no. 5	732	1,209.2	230.0	491.8	1333.5	256.0

Table 5.2. Legal maximum load weights for different vehicles based on the *Codex Theodosianus* 8.5.8, as converted to metric weights by Weller 1999 "Geography and Roads."

Vehicle term in Latin	Load Weight in Roman Pounds	Load Weight in kg
Angaria	1,500	492
Raeda	1,000	330
Currus	600	198
Vereda	300	99
Birota	200	66

Table 5.3. Average volumes of dolia in Pompeii and Ostia.

Vessels	**Average Volume**
Pompeiian Dolia	478 liters
Pompeiian Fermentation Dolia	553 liters
Pompeiian Dolia Buried in Bars/Shops	256 liters
Pompeiian Cylindrical Jars Buried in Bars/Shops	215 liters
Ostian Dolia	1008 liters

Table 5.4. Volume incisions on dolia from I.4.5, from Gatti 1903, 201-202, and dolia from storeroom (I. 19, now buried) near the *Horrea dei Mensores*, from Carcopino 1909, 359-364, with conversion to metric liters. Volume incisions are given in units of amphorae (26.2 liters), with S indicating half an amphora (13.1 liters) and Ɔ indicating a *sextarius* (1/48 of an amphora, 0.546 liters). * indicates a volume incision I recorded that differed from Gatti 1903, ** indicates a volume incision that was unpublished.

Property & Dolium	Ancient Volume Inscription (units of amphora)	Number of amphorae & *sextarii*	Volume (liters)
I.4.5 no. 1	XLII ƆIII	42 + 3 *sextarii*	1,102.0
I.4.5 no. 2	XLS	40.5	1,061.1
I.4.5 no. 4	XXXVIIIS ƆIII	38.5 + 3 *sextarii*	1,010,3
I.4.5 no. 10	XXVIIIS (XXXVIIIS)*	28.5 (38.5)*	746.7 (1,008.7)*
I.4.5 no. 11	XLVII	47	1,231.4
I.4.5 no. 12	XLII ƆII	42 + 2 *sextarii*	1,101.5
I.4.5 no. 16	XLS	40.5	1,061.1
I.4.5 no. 17	XLII	42	1,100.4
I.4.5 no. 19	XXXVIS ƆII	36.5 + 2 *sextarii*	957.4
I.4.5 no. 20	XXXIXS ƆII	39.5 + 2 *sextarii*	1,036
I.4.5 no. 22	XXXIIIS	33.5	877.7
I.4.5 no. 23	XLS	40.5	1,061.1
I.4.5 no. 24	XXXVS	35.5	930.1
I.4.5 no. 25	XLIIIS	43.5	1,139.7
I.4.5 no. 26	XXXIXS ƆII	39.5 + 2 *sextarii*	1,036
I.4.5 no. 27	XXXIIS	32.5	851.5
I.4.5 no. 28	XXIXS ƆII	29.5 + 2 *sextarii*	774
I.4.5 no. 29	XLI	41	1,074.2
I.4.5 no. 30	XLIII	43	1,126.6
I.4.5 no. 31	XLIIIS	43.5	1,139.7
I.4.5 no. 32	XLIIS	42.5	1,113.5
I.4.5 no. 33	XXXIXS ƆIII	39.5 + 3 *sextarii*	1,036.5
I.4.5 no. 35	XLIS	41.5	1,087.3
V.6.5 no. 68	XXXVIII ƆIII**	38 + 3 *sextarii***	997.2**
I.19 no. 3	XXIII	23	602.6
I.19 no. 4	XXXV	35	917
I.19 no. 5	XXVI or XXXVI	26 or 36	681.2 or 943.2
I.19 no. 6	XXXIV	34	890.8
I.19 no. 7	XXXIIS or XXXIIƆ	32.5 or 32 + 2 *sextarii*	851.5 or 839.5
I.19 no. 8	XXXII	32	838.4
I.19 no. 14	XXXVIII	38	995.6
I.19 no. 15	XXXIV	34	890.8
I.19 no. 16	XXIX	29	759.8
I.19 no. 21	XLVS	45.5	1,192.1