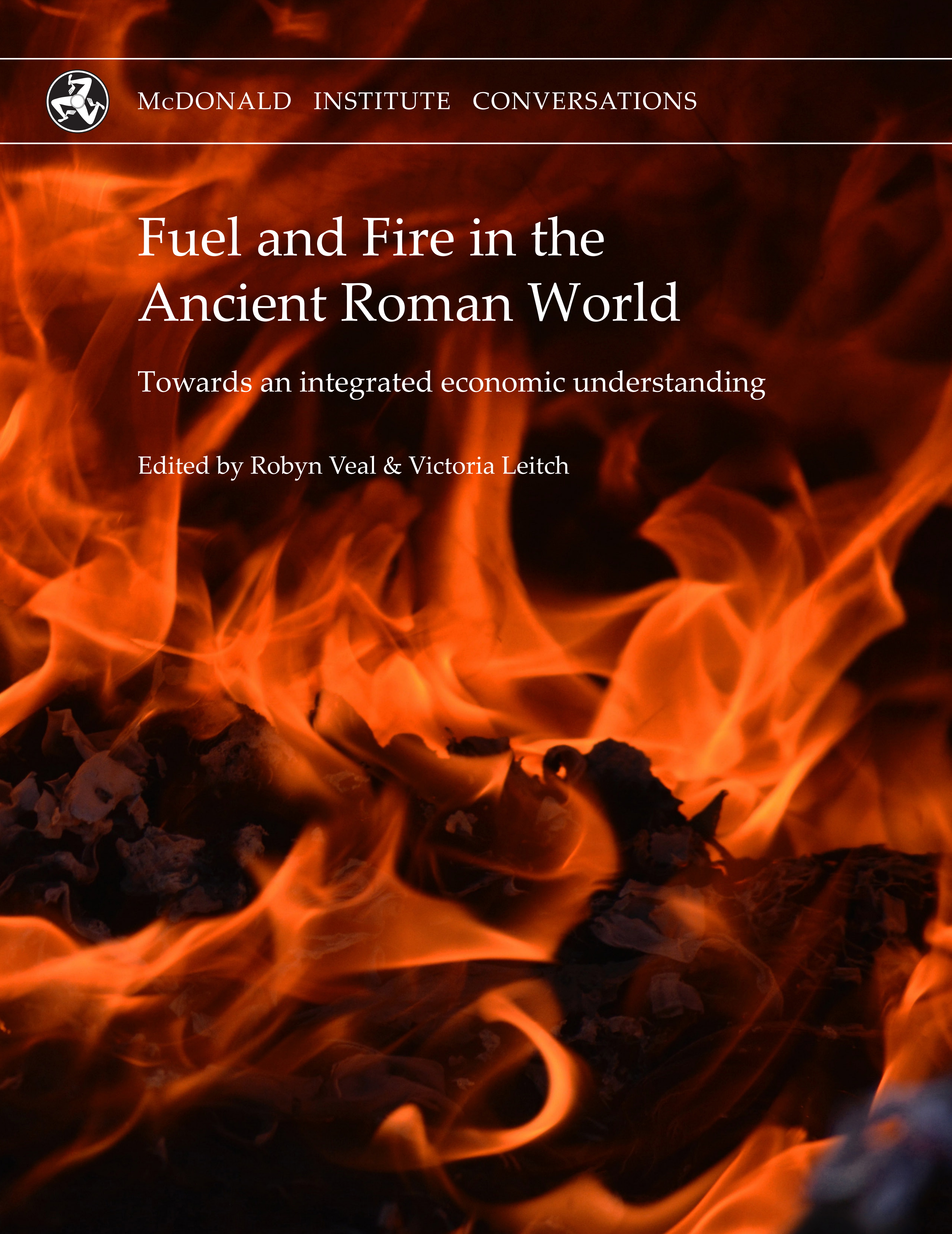

McDONALD INSTITUTE CONVERSATIONS

Fuel and Fire in the Ancient Roman World

Towards an integrated economic understanding

Edited by Robyn Veal & Victoria Leitch

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with contributions from
Jim Ball, H.E.M. Cool, Sylvie Coubray, David Griffiths, Mohamed Kenawi, Victoria Leitch, Archer Martin, Ismini Miliaresis, Heike Möller, Cristina Mondin, Nicolas Monteix, Anna-Katharina Rieger, Tony Rook, Erica Rowan, Robyn Veal, Véronique Zech-Matterne

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Preface

This book arises from a conference held at the British School at Rome, and the Finnish Institute in Rome, in March 2013, entitled Fuel and Fire in the Ancient Roman World. The conference represented the first real attempt to try to bridge the gap between 'top-down' generalized models about Roman energy consumption (itself, still a relatively new area of research), and research carried out by artefact and environmental specialists. In many ways it exceeded our expectations, although it probably raised more questions than it answered. As fuel is used in many different domestic and industrial contexts, the papers were very heterogeneous; some presenters came from a strong archaeobotanical background, which is a central area for fuel research, while others came from social, technical and economic spheres, opening up the discussion beyond archaeobotany. Some papers presented more 'qualitative' rather than 'quantitative' results but, as a new research area, this was inevitable and qualitative evaluation can provide the framework for approaching quantitative studies. Nevertheless, useful quantitative beginnings are proposed in a number of papers. Although focused on the Roman period, the research often extended beyond this chronological span, to help contextualize the results.

We gratefully acknowledge the support and assistance of the British School at Rome and the *Institutum Romanum Finlandiae* (Finnish Institute of Rome). In particular we thank Professor Katariina Mustakallio, then director of the *IRF*, for generously hosting the conference lunch on the final day. The financial support of the Oxford Roman Economy Project, through Professor Andrew Wilson, and a significant private donation from Mr Jim Ball, former President, Commonwealth Forestry Association (administered through the BSR Rickman Fund) allowed speakers' travel, accommodation and subsistence costs to be covered, as well as a contribution towards publication costs. Professor Wilson and Mr Ball both provided much appreciated moral support and intellectual input, acting as our major discussants. The McDonald Institute for Archaeological Research, through its Conversations series, also helped fund publication. Professor Graeme Barker (McDonald Institute director to September 2014), Professor Cyprian Broodbank (current director), Dr James Barrett (current deputy director) and Dr Simon Stoddart (former acting deputy director) all provided advice and guidance over time. This was much appreciated. Dora Kemp provided initial advice on manuscript preparation, and after her untimely death, Ben Plumridge took over the practical side of production. Maria Rosaria Vairo, then a Masters student of the University of Lecce, and Dana Challinor, a doctoral student at the University of Oxford, provided significant voluntary support during the conference and we thank them both profusely. Robyn Veal would also like to acknowledge the long-term financial and intellectual support of the Department of Archaeology, University of Sydney, through much of her early work on fuel. This led to the opportunity of a fellowship at the BSR, and the idea for this conference. The feedback from reviewers has greatly improved the book.

Robyn Veal & Victoria Leitch

Chapter 7

Necessity is the mother of invention: the fuel of Graeco-Roman pottery kilns in the semi-arid Eastern Marmarica

Heike Möller & Anna-Katharina Rieger

Pottery production is a resource-intensive industry, in antiquity as today, because it requires clay and water for making the pots and fuel for firing them. When we find a pottery production site in a resource-poor environment, the first question that arises is 'How were these requirements met?' The Eastern Marmarica, situated at the northern fringe of the Libyan Desert (Fig. 7.1), represents exactly such a case: in this semi-arid environment, a large number of ancient pottery production sites have been found, dating from Ptolemaic to Roman or, possibly, Late Roman times. This paper focuses on investigating how the potters there obtained the necessary materials for production, and in particular the fuel required.

The Eastern Marmarica region is predominantly covered by steppe, with little and variable precipitation; vegetation consists of shrubs and grasses extending across the tableland south of the coastal strip. Only along the coastline, with its Mediterranean climate, is it possible to grow trees and crops (Fig. 7.2). On the tableland, agricultural activity is only possible due to elaborate practices of water and soil harvesting (Vetter, Rieger & Nicolay 2009). In Graeco-Roman times, these systems were operated by a rural population that was able to produce a surplus of agricultural goods. The pottery production attested in the region supplied the need for transport and storage vessels as well as for common wares (Rieger & Möller 2011; Möller 2015). But where did the water to process the clayey soil come from? How were the kilns fired, and what kind of fuel was available to the ancient potters? Archaeological and archaeobotanical analyses, as well as ethnoarchaeological parallels found in modern pottery production in Egypt, have been applied to help understand what kind of fuel made pottery production in this resource-poor environment possible (a comparable approach is made by Kenawi & Mondin in this volume).

The fuel consumers: pottery production and kilns in the Eastern Marmarica

More than 55 pottery production sites were active between Ptolemaic and Roman times in the surveyed area and attest to a considerable demand (Rieger & Möller 2011, 144–7; Fig. 1). Judging by the size of the pottery waster heaps, pottery production in the Eastern Marmarica reached a very high output at some sites. A peak of production may be verified in the second to fourth century AD (Rieger & Möller 2011, 161–65 and table 1; Möller 2015). Consequently, over time, huge amounts of fuel for firing the kilns were needed. It is almost impossible to make accurate calculations as to the output and number of vessels produced. However, the sheer number of kiln sites producing within the same time period shows that the potters in the Eastern Marmarica produced vessels on a scale comparable to the region around Lake Mareotis (Empereur & Picon 1998). We can assume that the activity of the pottery workshops was most probably seasonal, as occurs today at Egypt's modern pottery sites. Then, as now, production likely coincided with harvesting and harvest processing times. During these periods, it is probable that a kiln was filled and fired every week (see also Martin, this volume, for information on modern pottery production in Egypt as a comparison). The large kilns, the dimensions of which are known in two cases – Wadi Qasaba, see below, and Bir Abu Sakran – have an estimated capacity of 350 amphorae. Thus, by firing every week, a workshop could produce about 1400 amphorae in a month. How many months a year a workshop and its kiln were in use is impossible to know but it is unlikely that they were active throughout the entire year.

At two of the pottery production sites in the Eastern Marmarica, the kiln and the waster heap have been excavated in order to examine the details of the

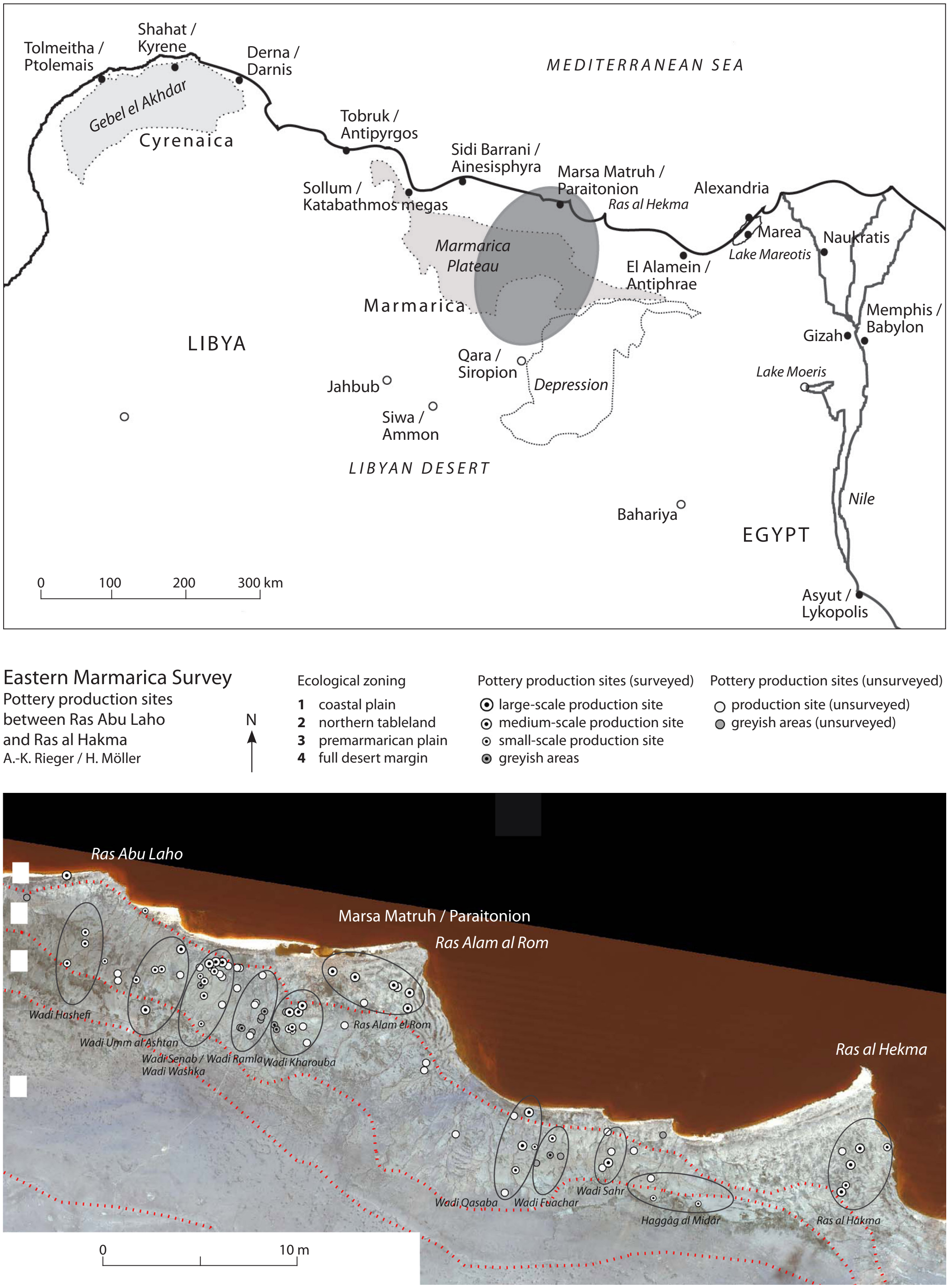


Figure 7.1. *Above: Map of the Marmarica showing the investigation area (after Rieger, Möller, Valtin & Vetter 2012, Fig. 1). Below: Pottery production sites in the Eastern Marmarica (after Rieger & Möller 2011, Fig. 2).*

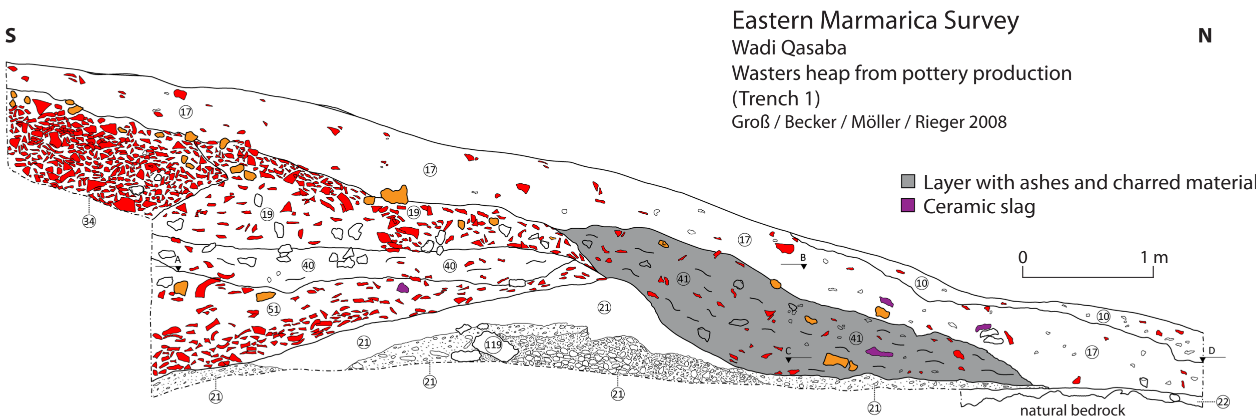
Figure 7.2. *Natural prerequisites along the coastline in the Eastern Marmarica. Above: Wadi Kharbouba; below: Wadi Umm el-Ashdan (photos A.-K. Rieger, O. Klammer).*

production process and the applied technology as well as to clarify the chronology of the vessels that were produced and the lifespan of the workshop.

Wadi Qasaba

Wadi Qasaba is situated 28 km east of Marsa Matruh. This site is a relatively large pottery production area and lies 4 km south of the coast, between the branches of the wadi, and is embedded in a settlement (Rieger & Möller 2011, 154–7). The finds at the site confirm that the settlement and the pottery production site were in use between the end of the second century AD and the fourth century AD. The bean-shaped mound of wasters rises up to 3 m above the ground and it is a prominent feature in the landscape (Fig. 7.3, above). It contains mostly wasters, sherds and slags of amphorae and some common wares. The kiln itself, sunk into the ground, was discovered 'leaning' against the waste heap and could be reconstructed as an up-draught kiln (Rieger & Möller 2011, 154–5; Möller 2015). This kind of kiln is frequently used in Egypt (El-Ashmawi 1998; Majcherek & Shennawi 1992; Dixneuf 2011) and elsewhere (Bonifay 2004). It is constructed in a chimney form, with an upper and lower chamber separated by a stacking platform providing indirect heat and protecting the product from smoke. This construction, combined with being set deep in the ground, provides a high thermal efficiency (Bourriau, Nicholson & Rose 2000), a technical requirement for pottery production on a more sophisticated level. The size of the kiln (the inner diameter of the stacking platform measures *c.* 5.5m) and the huge quantity of wasters, indicate pottery production on a large scale. Along with some common wares, mainly amphorae – type AE 3 (recently Dixneuf 2011, 97–128) and AE 3–6 (Möller 2015) – were fired. About 100 m northeast of the potter's workshop, a facility for producing liquids, most probably wine, was discovered (Fig. 7.3, below). Two large basins measuring *c.* 5.5 × 2.5 m are preserved, one of which has been excavated. They lie behind a spouted stone leading to a collecting vat, where fermentation and settling took place. The excavated basin is preserved to a height of 0.2–0.3 m and is lined with waterproof plaster. Judging by its position, it was used as a treading floor. It inclines by about 3.5 per cent towards the northern side, where one would expect the collecting vat.

The facility is comparable to wine presses found around Lake Mareotis (Empereur 1993; Rodziewicz 1998). In the Eastern Marmarica, presses were found mainly near pottery production sites. The close spatial relationship is due to an organizational relationship between the products that each facility provides, both the vessels and the wine (e.g. Ruffing 2001, 58; for the ecological conditions and favourable wine growing areas, see below). The enormous output of vessels and



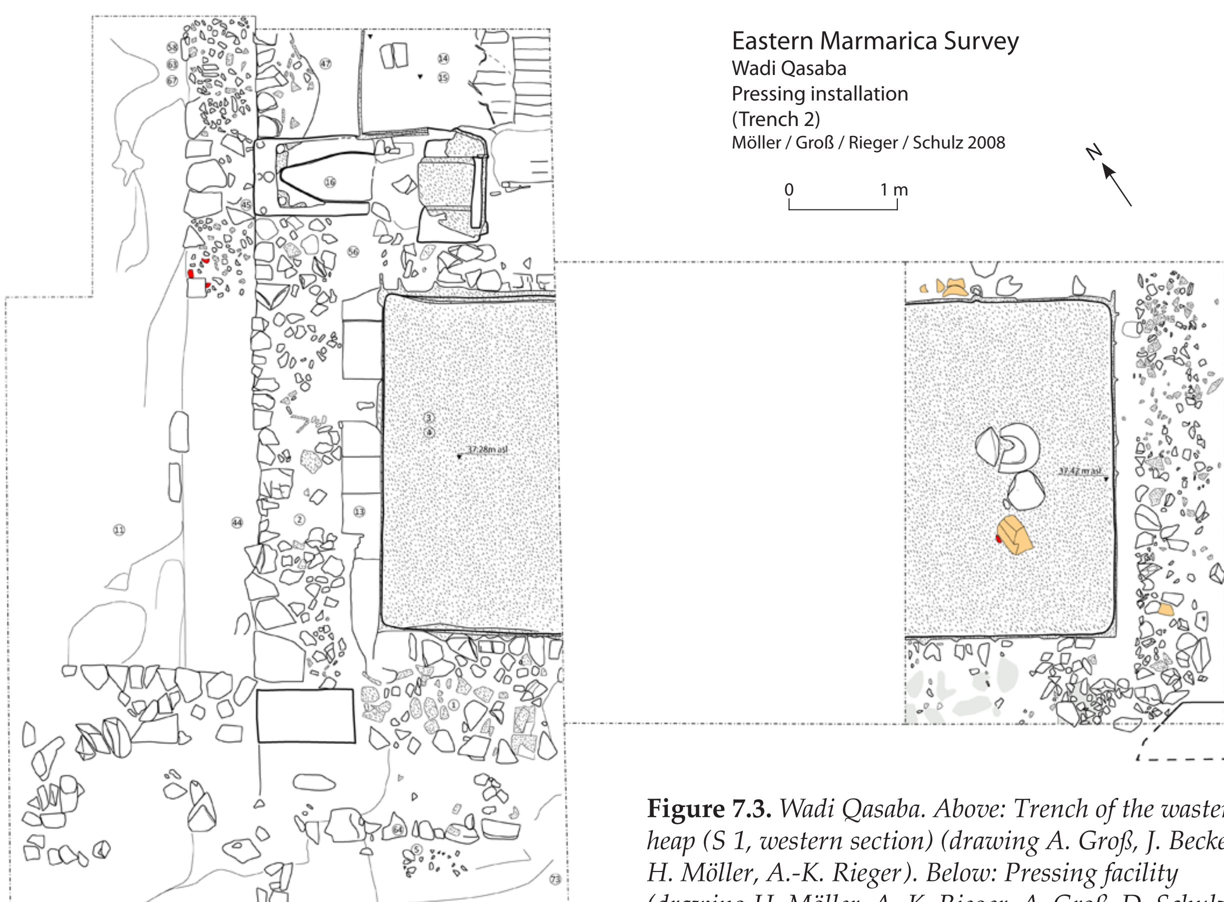
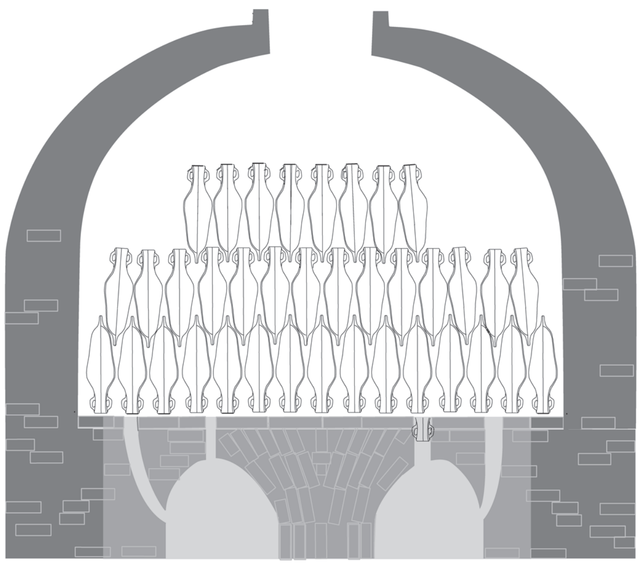


Figure 7.3. *Wadi Qasaba. Above: Trench of the wasters heap (S 1, western section) (drawing A. Groß, J. Becker, H. Möller, A.-K. Rieger). Below: Pressing facility (drawing H. Möller, A.-K. Rieger, A. Groß, D. Schulz).*

the size of the pressing facility at Wadi Qasaba both attest to the considerable economical potential of this semi-arid area. In this case, the high demand for raw materials required to produce such a great number of vessels proves the rather unexpected agricultural capacities in the Marmarica and vice versa. The ancient agricultural system also answers, in part, the question of what fuel can be used in a desert-like region, as is discussed later.

Wadi Umm el-Ashdan

A smaller kiln site was investigated in the Wadi Umm el-Ashdan, a settlement at the western branch of the wadi, 16 km west of Marsa Matruh. Eight small kilns were active in the settlement itself during the Roman period (Rieger & Möller 2011, Tab. 1, no. 38 and 158–9); there was also a larger kiln, adjacent, not discussed here. A possible reconstruction is provided of the style of the small kilns (Fig. 7.4, above). Complementing and



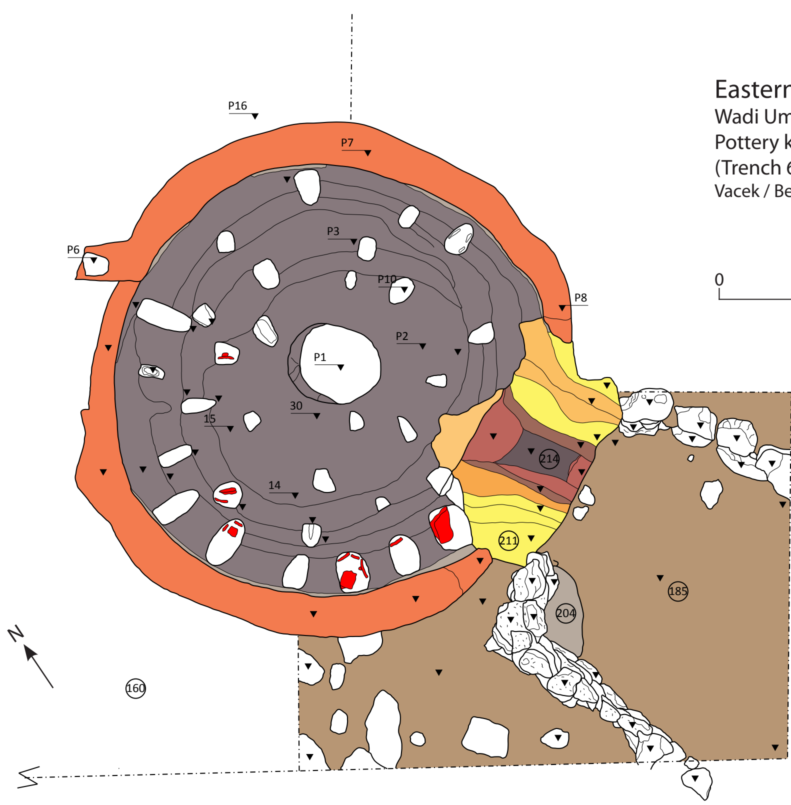


Figure 7.4. *Wadi Umm el-Ashdan. Above: Reconstruction of the pottery kiln (drawing H. Möller, A.-K. Rieger). Below: Trench of a pottery kiln (S 6, plan view) (drawing A. Vacek, J. Becker).*

contrasting the examination of the large workshop/kiln complex at Wadi Qasaba discussed above, these small kilns demonstrate production on a completely different scale. Their output was clearly much lower than that of the Wadi Qasaba complex, probably covering only the demands of the el-Ashdan inhabitants. It remains unclear what kind of pottery was produced in these small kilns, since they were used as dumps after they were abandoned. The small number of pottery wasters does not indicate a specific type of pottery, but if for local consumption, the pottery was probably mainly common wares, such as for food preparation, as well as tablewares for daily use. However, many amphorae are among the find materials.

Of the eight kilns, the one chosen for a detailed investigation is only 3.5 m in diameter (Fig. 7.4, below) and was probably active in the second and third century AD, as can be inferred from the finds of AE 3 and table- and cooking ware (Rieger & Möller 2011, 163; Möller 2015). Still a (smaller) up-draught kiln, it also differs slightly in design from the one at Wadi Qasaba, as it has a differently built stacking platform. The production site does not have huge waster heaps. Only areas with a mixture of sediment and sherds attest to the activity of the kiln. The greyish colour of the deposit may be the result of cleaning the firing channel that leads south from the firing chamber (Fig. 7.4, below). However, a layer or accumulation of charred material, as in the case of Wadi Qasaba, could not be identified. Consequently, only general assumptions can be made about how the Wadi Umm el-Ashdan small kilns were fired.

How to generate biomass: agricultural waste and natural vegetation as fuel supply for pottery workshops

Pursuing the question of how to fuel a kiln in a resource-poor environment leads to the more general question of what organic and combustible material can we expect to find there, i.e. what potential biomass existed. Since the natural vegetation, as already mentioned, is limited to shrubs and grasses and produces a few trees only along the coastal strip, the woody plant biomass is insufficient to meet the fuel requirements of the kilns. Fuel has to be augmented by other means when it is needed on a larger scale. Especially on the northern tableland, agricultural activity is feasible due to an elaborate system of water and soil harvesting. The ancient settlements, such as Wadi Qasaba or Wadi Umm el-Ashdan, relied on the areas that became cultivable by these improvements to the pre-existing ecological conditions. Thus, not only life based on agriculture became possible, but also the amount of available organic material required for firing the kilns also increased.

Agricultural production on the northern tableland

Three different types of cultivable land can be distinguished depending on the water and soil harvesting installations and run-off conditions: embanked fields (*kurum*); planting mounds (*teleilat el-einab*); and terraced fields. Their installation in ancient times was ascertained by OSL-dating of the accumulated soil layers behind man-made walls, embankments and bunds (Vetter, Rieger & Nicolay 2009, 12–7, fig. 16), whereas the close-by Graeco-Roman settlements (as at Wadi Umm el-Ashdan) or sherd scatters along the embankments or bunds provided archaeological evidence that the fields were used in antiquity.

The installation of tableland fields goes back to the second millennium BC (dated by the OSL method). They were more or less continuously active until the middle of the first millennium AD, and the earliest wadi terraces could be dated to the beginning of the first millennium BC (again by the OSL method). Tableland fields and wadi terraces are still in use today; only the stone-covered mounds represent an agricultural innovation that is no longer used. The estimations discussed below on the size of the ancient agricultural areas, their field capacities and possible crops are based on pedological and hydro-geographical analyses in the Wadi Umm el-Ashdan watershed. These estimations are supplemented by textual evidence and botanical research. Firstly, these assumptions serve as an approach to understanding the economic potentials and bases of livelihood of the people on the northern fringe of the Eastern Marmarica in antiquity. Secondly, they give an idea of how much biomass could be produced in the region.

1. Embanked fields (*kurum*)

Embanked fields are a specific feature of dry-farming in the Marmarica. The unique morphological layout of the region, with its slightly sloping tableland, allows the installation of fields, not only in the run-in zones (where the water has to be contained), but also in the run-off zones (Vetter, Rieger & Nicolay 2014, 45) (Fig. 7.5). The characteristics of the *kurum* increase the amount of available water and the soil depth, so that the cultivation of barley becomes possible, although the Arabic name actually implies the cultivation of grapes. According to the only preserved papyrus from the region, barley seems to have been the second most important crop in the fields of the Marmarica. The papyrus refers to an area a little further west of the investigated area (*P. Marm.*, Norsa & Vitelli 1931; Rieger 2017), where more than a quarter (26.5 per cent) of all taxed agricultural areas are barley fields. Furthermore, in the Roman period, taxation of the cereal crops of the region took place in Paraitonion, modern Marsa Matruh, as we learn from a papyrus from Oxyrhynchus (POxy 9, 1221). This

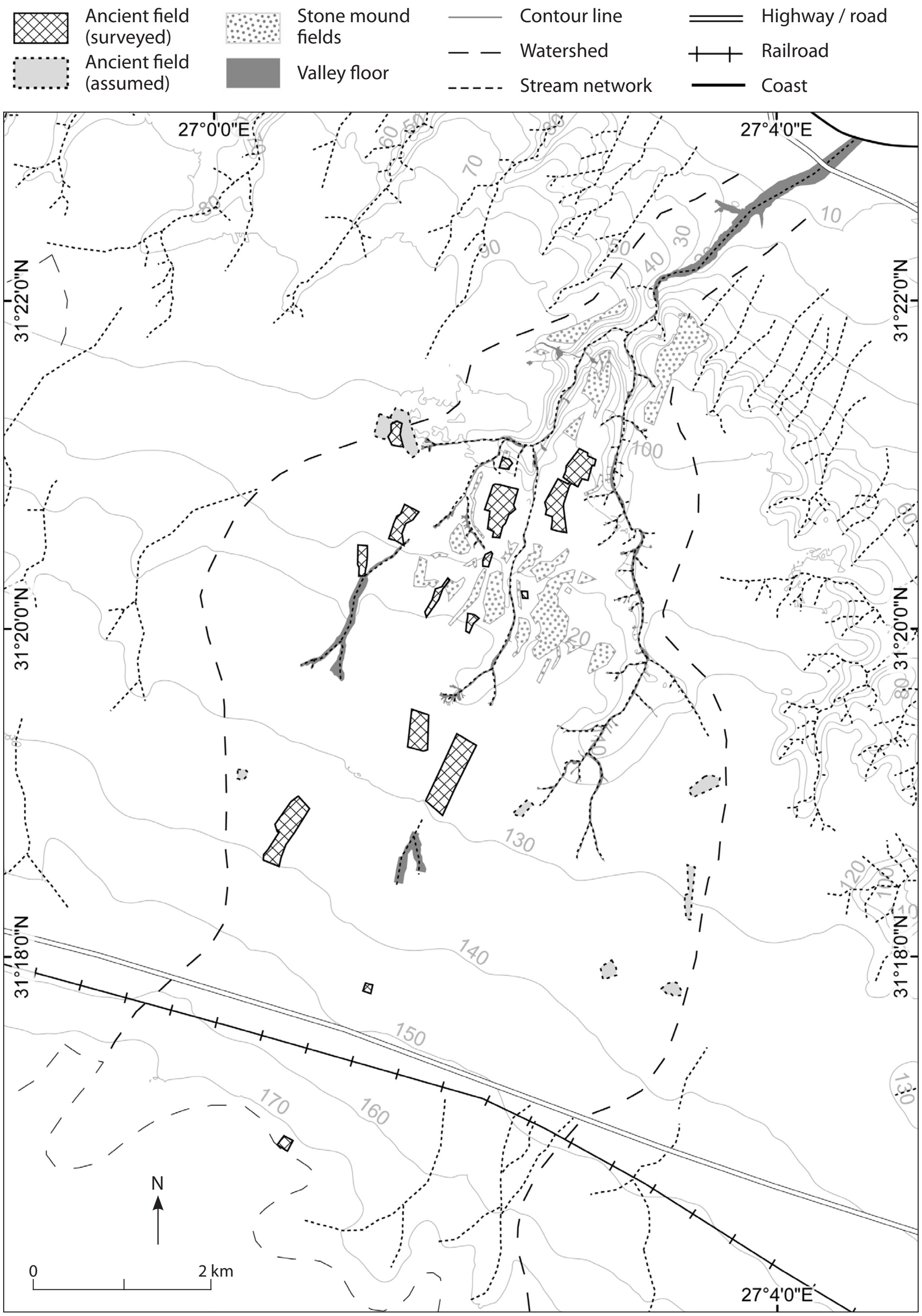


Figure 7.5. *Wadi Umm el-Ashdan. Different agricultural areas in the watershed system (map A. Nicolay).*

information confirms once more that crops were cultivated in the region. The area of the *kurum* in the Wadi Umm el-Ashdan system amounts to almost 1 sq. km, which corresponds to *c.* 2 per cent of the area within the watershed system (51 sq. km). If we assume a yield of *c.* 400 kg per ha (10,000 sq. km) (cf. Müller-Mahn 1989, 55), an annual yield of 40 tons of barley was possible on the fields close to the village.[1] The crop provided the basic carbohydrate requirement of the daily diet, in combination with some wheat and vegetables (see below). However, not only the grain itself was used but the chaff and straw as well. After threshing, the remains were an important resource, which was used as animal fodder; as temper for mud bricks; or as fuel.

2. Planting mounds (*teleilat el-einab*)

Numerous stone-covered mounds, spread across the entire tableland, are still visible today. This phenomenon is comparable to other semi-arid or arid regions, but their function is highly contested. Each with a diameter of 1–2 m, they cover an area of 3 to >6 sq. m. Their height does not exceed 0.5–0.8 m (Fig. 7.6). Each mound is enclosed by a circle of stones that is set into the ground. This feature makes them clearly an anthropogenic construction. Their fill consists only of unconsolidated sediment mixed with pieces of local limestone (Fig. 7.6). These cobble-sized stones are also used for neatly covering the mounds. The mounds, 7–15 m apart, are spread out close to scarps but also scattered over the level ground between the wadi branches (Fig. 7.5). In some cases, they seem

Figure 7.6. *Wadi Umm el-Ashdan. Above: View of planting mounds as they appear on surface (*teleilat el-einab*) (photo A.-K. Rieger). Below: Excavation of a stone-covered mound (photo A. Nicolay).*

to be placed in a line, but mostly they are randomly distributed, in contrast to the many examples of lined-up mounds consisting only of stones in the Negev.

In the Negev, the opposing explanations are that they functioned either as dew traps and were used as planting mounds, or that the stones were simply collected to clean the ground and thus facilitated the run-off (facilitating the run-off: Evenari, Shannon & Tadmor 1982, 127–30, Mazor 2001, 340; dew traps: Crawford 2008, 93–4, Lightfoot 1997, 210–12). Using satellite images, more than 1450 of these mounds can be counted in the watershed system of Wadi Umm el-Ashdan. They cover an area of 186,000 sq. m (0.18 sq. km), the equivalent of 0.45 per cent of the land within that wadi system (Fig. 7.5).

Although we do not have any data on the amount of water available for planting and the soil conditions in the stone-covered mounds, there is convincing evidence that they were used as planting mounds. In particular, we can assume a quite substantial viticulture in the region of the ancient Marmarica. Two ancient texts attest to viticulture and wine. The first source is Strabo (*Geog.* 17.1.14), who talks about the quality of Libyan wine produced west of Lake Mareotis, in comparison to wine from the Mareotis region itself. The second source is the *P. Marm.* (Norsa & Vitelli 1931; Rieger 2017): almost half of the agricultural regions mentioned in a type of tax list are vineyards. Furthermore, the text states that there are ἀμπελικαι δία χέρσου ἀρουραι (col. 1, l. 8), which means that a vineyard is planted on infertile land. Some areas of viticulture are bordered by wadi valleys (νάπη; col. 10 and 11, several lines). This description may apply to the planting mounds as we see them on the otherwise useless tableland in the northern parts of the Marmarica. The texts about viticulture, which are geographically rather vague, match the archaeobotanical evidence from the investigated area: wood from *Vitis vinifera* was found in the Roman layers of the settlement at Wadi Umm el-Ashdan (see below, and Fig. 7.7), so that most likely grapes were cultivated in the Eastern Marmarica. Bush vine or low-trained vines (as grown today on the islands of Santorini or Lanzarote) were feasible, because they grow close to the ground and thus would avoid the strong winds of the tableland.

Although the mounds themselves are easily counted, it is difficult to estimate their yield in grapes, because this depends on the plant variety and the precise climatic, hydro- and pedological conditions, which cannot be easily estimated. But assuming only two vines per mound, a huge amount of organic, combustible material would have become available over the year. Dead wood, cuttings and leaves accrued every season. Apart from these plant remains, there were also grape pressings. Both these agricultural 'waste' products helped to cover the demand for fuel.

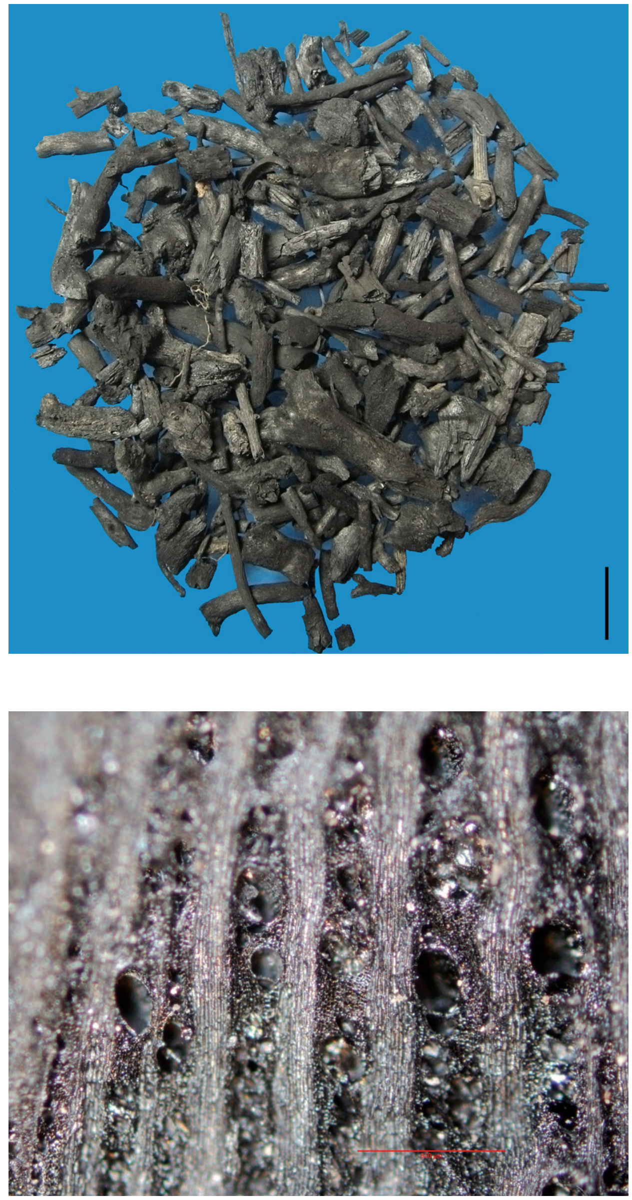


Figure 7.7. *Archaeobotanical remains from Wadi Qasaba and Wadi Umm el-Ashdan. Above: Wood of a* Tamarix *sp. (scale 1 mm) (photo A. G. Heiss). Below: Wood of* Vitis vinifera *(scale 500 µm) (photo V. Asensi Amorós).*

3. Terraced fields

A common and widespread way of farming in semi-arid or arid regions is to use water and soil harvesting systems established along wadi incisions. Lateral and cross dams form sediment traps, creating terraces of soil able to hold the run-off from the slopes (Fig. 7.5). Analogies to other semi-arid or arid regions can be found in

Tripolitania, Jordan and the Negev (Vetter & Rieger 2019; Evenari, Shannon & Tadmor 1982; Gilbertson & Chrisholm 1996). Figure 7.5 shows where water and soil harvesting walls of presumably ancient date could be measured in Wadi Umm el-Ashdan, allowing for a reconstruction of the ancient field system. The field areas generated by lateral and cross-sectional terracing were calculated according to the still visible height of the dams. These calculations tend to be minimum estimations, since the walls may have lost their upper stone layers.

Although we do not know how far the village plots of the Wadi Umm el-Ashdan settlement extended towards the north, we can estimate the terraced fields that were cultivated. The escarpment, where the tableland slopes down to the coastal plain, could possibly represent the natural border of the Wadi Umm el-Ashdan settlement. Adding up all wadi fields in this area, the cultivable land generated in the main wadi bed, at the tributaries and on their slopes covered 320,000 sq. m (0.32 sq. km), which is less than 1 per cent of the wadi system (a third of the slopes and wadi beds are terraced; Fig. 7.5).

Due to the relation between run-off zone and target area (Vetter, Nicolay & Rieger 2014), water and soil accumulated, making the terraces in the valleys capable of supporting tree cultures, such as fig, olive, almond and pomegranate. In addition, wheat, which needs more than 300 mm p.a. precipitation, could be grown in these plots. Garden cultures with legumes and vegetables were also possible. Since remains of figs and wheat are preserved (see below) and mentioned in the *P. Marm*. text (Norsa & Vitelli 1931; Rieger 2017) on the northern tableland, we can assume their cultivation in the main wadi and the small tributaries with their terraced fields. Assuming an area of 100 sq. m for one fig tree, for example, up to 3200 trees could have been grown. As in the case of barley or vines, they produced biomass, and their dead leaves, cuttings and dry branches could be used for firing kilns.

These three methods of growing crops and trees on the northern tableland show how floral and small woody biomass could be generated through agricultural exploitation of the region. The botanical macro-remains from the two sites where kilns were excavated give a glimpse of the indigenous and anthropogenic vegetation and, thereby, of the material that is likely to have been burnt in these workshops.[2]

Botanical remains from Wadi Qasaba

Due to the semi-arid environment in the northern parts of the Eastern Marmarica, botanical remains are likely to be preserved mostly in charred form. Two pieces of wood and some pieces of sub-fossil/dry remains were found in the region of the northern tableland. Remains of charred wood, seeds and fruits were flotated from soil samples (mesh size 0.5 mm) and two pieces of sub-fossil/dry wood were found preserved in the soil. Charred particles and pieces reflect only partially the plants expected in the ancient layers, since some plants burn completely, whereas others become un-diagnostic due to poor preservation. All samples contained few, and only poorly preserved, remains, due to the ecological and archaeological preservation conditions. During the excavation of the kiln at Wadi Qasaba, the firing chamber was reached, but no charcoal was found. However, the trenches in the waster heaps brought to light thick layers of it and provided charred botanical remains (Fig. 7.3). These contexts can be interpreted as deposits from cleaning out the firing chamber, and they provide quite detailed information on the fuel deposited on the waster heap after the firings. Other remains were found in the area where slag has been dumped and on the kiln's stacking platform. In the grape pressing facility, *Hordeum vulgare* and *Triticum aestivum* (Fig. 7.8) as well as synanthopic plants, such as *Plantago* sp., *Malva parviflora* and Cyperaceae (sedge), were discovered as components of the available biomass.

Figure 7.8. *Archaeobotanical remains from Wadi Qasaba. Above:* Hordeum vulgare*, rachis. Below:* Triticum aestivum*, caryopsis. (Scale 1 mm; photos A. G. Heiss.)*

Figure 7.9. *Above: Vegetation in the Wadi Umm el-Ashdan and Wadi Kharouba:* Salsola *and* Artiplex Halimus, *Chenopodiaceae species (photo A. Nicolay). Below: Vegetation in the desert of the Marmarica Plateau:* Acacia *(photo H. Möller).*

Besides the rather scattered and small pieces of charred organic material in the layers of the wasters heap (trenches 1 and 3), fairly homogeneous charcoal samples, consisting of *Tamarix* sp. (tamarisk) and a large number of seeds from the Chenopodiaceae (weed) family, were also present. Tamarisk, an indigenous plant, is the only tree that was used as fuel, as far as can be deduced from the botanical remains. It occurred in the ash layer of the wasters' heap (from the cleaning of the firing chamber) and on top of the stacking platform of the kiln. Tamarisk is still a common tree in the Nile valley as well as in the depressions and wadi of the steppe or desert landscape in Mediterranean Africa and Asia (Thanheiser 2011, 82) (Fig. 7.7). The tree grows in the coastal zone of arid Eastern Marmarica where it apparently was an endemic plant also in antiquity, as the finds in Wadi Qasaba suggest. *Salsola* spp. (saltworts) as well as *Artiplex* spp. (saltbush/orach), are two shrub genera native to Egypt and examples are still found in the steppe zone of the northern tableland. These belong to the family of Chenopodiaceae, present among the finds from Wadi Qasaba (Fig. 7.9). Finds of saltwort at Abar el-Kanayis on the Marmarica Plateau to the south and at Wadi Umm el-Ahsdan confirm the existence of this type of shrub in antiquity (see below, and Rieger, Möller, Valtin & Vetter 2012, 140). Their use as

Table 7.1. *Botanical finds from the large pottery production site in Wadi Qasaba (WQ S 1, 3, 4), the workshop (WQ S 9) and the wine press (WQ S 2); ch=charred and sd=sub-fossil/dry.*

	Taxa / family		Number of remains	Trench/context	Preservation	Analysis by
Finds from wasters heap and kiln	*Tamarix nilotica*	Tamarisk	5	S 1, 40	ch	U. Thanheiser
	Apiaceae	Umbelliferous plants	1	S 1, 40	sd	U. Thanheiser
	Asteraceae	Daisy family	1	S 1, 40	ch	U. Thanheiser
	Asteraceae	Daisy family	1	S 1, 40	sd	U. Thanheiser
	Chenopodiaceae	Goosefoot family	1	S 1, 40	ch	U. Thanheiser
	Lamiaceae	Labiate	4	S 1, 40	sd	U. Thanheiser
	Chenopodiaceae	Goosefoot family		S 1, 41	ch	A. Fahmy
	Fabaceae *Trifolium*-type	Clover	3	S 3, 56	ch	U. Thanheiser
	Caryophyllaceae	Broomrape, bedstraw	1	S 3, 56	ch	U. Thanheiser
	Malva parviflora	Mallow	1	S 3, 56		
	Portulaca oleracea s.l.	Portulaca / hogweed	1	S 3, 56	ch	U. Thanheiser
	Cerealia		1	S 3, 56	ch	U. Thanheiser
	Chenopodium murale	Nettle-leaved goosefoot	1	S 3, 56	ch	U. Thanheiser
	Typha sp.	Reed mace, bulrush		S 3, 56	ch	A. Fahmy
	Tamarix sp.	Tamarisk		S 4, 128	ch	A. Fahmy
Finds from workshop and wine press	*Triticum aestivum* s.l./ *durum*	Breadweed, durum	1	S 9, 1007	ch	U. Thanheiser
	Hordeum vulgare	Barley	7	S 2, 67	ch	U. Thanheiser
	Asteraceae	Daisy family	3	S 2, 67	ch	U. Thanheiser
	Cyperaceae	Sedge family	3	S 2, 67	ch	U. Thanheiser
	Poaceae	Grass family	1	S 2, 67	ch	U. Thanheiser
	Plantago sp.	Plantain	3	S 2, 67	ch	U. Thanheiser
	Chenopodium album	White goosefoot	1	S 2, 67	ch	U. Thanheiser
	Malva cf. *parviflora*	Mallow	1	S 2, 67	ch	U. Thanheiser

charcoal in a comparable environment is attested by finds at Quseir el-Qadim on the Red Sea coast (Van der Veen 2011, 220–1).

Other plant remains represent a rather scattered picture of the common segetals (weed types growing within grain crops). The occurrence of *Typha* sp. seems to be exceptional in a dry environment, but this hydrophilic plant, especially the salt-tolerant species, can grow in sebkhas and salt marshes close to the sea as well as beside ponds in the wadi beds (for example Wadi Umm el-Ashdan). Since fragments of cereals were found among the ashes in the waster heap and the adjacent workshop building (as well as in the pressing installation, Fig. 7.8), we can assume that agricultural residues and plants taken from the vegetation of the surroundings were burnt. The quite large wine press close to the kiln suggests that grapes were processed here. Although no remains of woody grapevines or grapes were found, cuttings from the grapevines in the area as well as the pressings produced by the wine press could have been used as fuel for the kiln.

The archaeobotanical results not only indicate that the vegetation pattern in Graeco-Roman times was similar to today, but also that, as we have seen in Wadi Qasaba, the semi-arid to arid ecological conditions and the resource-poor environment in antiquity are reflected in the mixed and sometimes meagre material available for firing a kiln.

Botanical remains from Wadi Umm el-Ashdan

In the settlement of Wadi Umm el-Ashdan, less information could be discovered. The ashes from the firing channel of the small kiln did not yield any identifiable remains. The ashes brushed out from cleaning the kiln produced only unidentifiable bits of charred plants; however, they did contain calcined pieces of snail shell.[3] Snail shells are present in many ancient contexts in the Eastern Marmarica (Pöllath & Rieger 2011, 169–70; Rieger & Möller 2012, 21, 25), since snails were part of the diet. Their occurrence could mean that every available waste was used for firing the kiln, but they may also just be refuse, because this kiln was

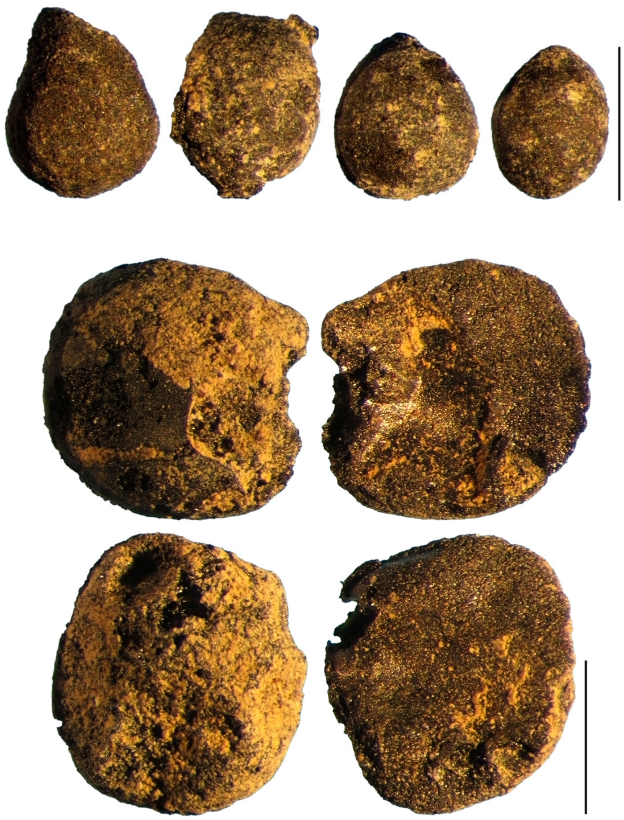


Figure 7.10. *Archaeobotanical remains from Wadi Umm el-Ashdan. Above:* Ficus carica, *achene. Below: Fabaceae, seed. (Scale 1 mm; photos A. G. Heiss.)*

later used as a dump. Although plant remains from the kiln are lacking, we can reconstruct the organic material that was produced in the area of Wadi Umm el-Ashdan through the botanical remains from other contexts of the settlement. Charred parts of figs (*Ficus carica*) and legumes (Fabaceae, cultivated species) were found in the fill of one of the circular structures (trench S 4) dated to Ptolemaic times by the ceramic evidence (Fig. 7.10). *Phoenix dactylifera* (date palm) occurs in one context. Grain, as found at Wadi Qasaba, is not present among the finds from Wadi Umm el-Ashdan, which may be due to the small number and volume of samples. However, the cultivation of barley is highly plausible on the embanked fields close to the settlement (Fig. 7.5).

Some synanthropic as well as indigenous plants are preserved. Among the latter, even shrubs and trees occur. Saltwort, and *Acacia* sp. (type of wattle), represent the native shrub and tree vegetation of the northern tableland and the northern Marmarica Plateau (Fig. 7.9). Saltwort was certainly used for fuelling the kilns, as the samples from Wadi Qasaba have shown. The occurrence of charred *Acacia* may indicate that this wood was used for the same purpose (Thanheiser 2011, 87 with table 3, dealing with the possible utilization of these plants in the prehistoric Dakhleh Oasis). Some unexpected finds consisted of pieces of Pinaceae (possibly *Pinus sylvestris*) wood. Pines are difficult to differentiate, but in the case of high altitude European groups, some are distinguishable to species level. They are preserved as sub-fossil/dry remains and were used

Table 7.2. *Botanical finds from the area of the settlement in Wadi Umm el-Ashdan (UA S 4, 8, 10, 12, 14); ch=charred and sd=sub-fossil/dry.*

Taxa / family		Number of remains or weight	Trench/context	Preservation	Analysis by
Vitis vinifera	Vine		S 14, 909	ch	V. Asensi
Vitis vinifera	Vine		S 14, 913	ch	V. Asensi
Vitis vinifera	Vine		S 12, 612	ch	V. Asensi
Salsola sp.	Salsola		S 12, 607	ch	V. Asensi
Pinus cf. *(sylvestris)*	Scotch pine / Baltic redwood	15.5 g	S 10, 313	sd	V. Asensi
Phoenix dactylifera	Date palm		S 8, 514	ch	A. Fahmy
Cedrus sp.	Cedar	56.5 g	S 8, 580	sd	V. Asensi
Salsola sp.	Salsola		S 8-7, 768	ch	V. Asensi
Acacia cf. *nilotica*	Acacia	1	S 8, 531	ch	V. Asensi
Salsola sp.	Salsola		S 8, 531	ch	V. Asensi
Ficus	Fig tree	4	S 4, 86	ch	U. Thanheiser
Plantago	Plantain	1	S 4, 86	ch	U. Thanheiser
Malva sp.	Mallow	1	S 4, 86	ch	U. Thanheiser
Poaceae	Grass family	4	S 4, 86	ch	U. Thanheiser
Fabaceae *Trifolium*-type	Clover	3	S 4, 86	ch	U. Thanheiser
Fabaceae (cult)	Clover	2	S 4, 86	ch	U. Thanheiser

at least in one case for a sarcophagus or wooden box in a burial in the ancient settlement of Wadi Umm el-Ashdan. A piece of *Cedrus* sp. (cedar) was found in a basin. These conifers are not indigenous to Egypt. Their wood was imported and, therefore, an expensive commodity, most likely not intended to be used for fuelling kilns in the first place.

More important for the question of fuel provision, however, are three pieces of charred grapevine (*Vitis vinifera*, Fig. 7.7). They were discovered in the circular structures, which are most probably dovecotes, and in a house context. These remains clearly confirm the assumed function of the stone-covered mounds as *teleilat el-einab* (planting mounds). The great number of grapevines producing wood and other residue means that there was plenty of material available for firing the kilns on the northern tableland. These results match the pedological and hydrological data, and the reconstruction of the dry-farming system in the region as described above.

Modern pottery workshops – an ethnoarchaeological approach to fuelling kilns

Pottery production in Egypt is still carried out today, although it is not nearly as widespread as it was in the last century. The production is concentrated along the Nile valley, the delta region (Redmount & Morgenstein 1996; Koehler 1996; Ballet & von der Way 1993; Kenawi 2012), modern Cairo (van As, Duistermaat, Groot et al. 2009), and the Fayoum and the Eastern Oasis (e.g. Dakhla: Henry Heinen 1997; see Kenawi & Mondin this volume). Visits by the authors to modern kiln sites in the western delta in recent years helped not only to understand the process of pottery production itself but also clarified questions concerning the raw materials, such as water, clay and fuel, their processing and the work sequence.

Interviews with the potters showed that the choice of fuel is quite random (see also Martin in this volume). However, the potters rely on some basic materials, especially scraps of wood and sawdust. This seems to be the preferred fuel, along with by-products from processing agricultural goods, seasonal agricultural waste from plants, such as sugar cane and rice, or any other kind of combustible material. It is plausible that the way in which modern potters collect any accessible fuel could have also been adopted in the ancient sites. Woody plants, fodder plants, straw and chaff, remains from the pruning of grapevines and fig trees, pressings from grapes, and animal dung and droppings; whatever was regionally and seasonally available was used as fuel. This model of an ad hoc fuel supply does not preclude the possibility that fuel was imported to the site from elsewhere. Since our reconstruction of the agricultural production allows to assume a surplus agricultural economy in this region, we can relinquish the idea that tons of wood were needed to fuel the kilns in the Eastern Marmarica.

In agreement with the assumed mixed fuelling of the kilns, there is no correlation between the spatial distribution of pottery workshops in the Eastern Marmarica and the availability of a certain kind of fuel. Rather, easy access to the raw materials of water and clay is the criterion for choosing the location for a kiln. This is the same pattern we observe in modern pottery production sites.

Conclusion

Our approach to understanding the fuel that was used for Graeco-Roman pottery production in the semi-arid environment of the Eastern Marmarica has been twofold. On an archaeological micro-scale, ash deposits from pottery kilns were analysed, whereas on an archaeological macro-scale environmental reconstruction was undertaken with bio- and geo-archaeological methods to understand the ecological conditions and agricultural activities as local providers of plant biomass suitable for firing.

The Eastern Marmarica is an almost desert-like environment with little vegetation. Nevertheless, the 55 pottery production sites consumed considerable amounts of fuel that somehow had to be procured. While the evidence is insufficient to determine the frequency of firing processes in the workshops, we know that many of them produced wares contemporaneously, and over a period of some centuries. Botanical macro-remains in ash layers of excavated kiln sites in Wadi Qasaba reveal that a mixture of different plants was burnt. Besides indigenous trees and shrubs, the by-products of agricultural procedures, such as remains from pruning, and grape pressings, as inferred from the location of the wine press, are likely to have been burnt, even though this kind of fuel is not of the highest quality. At the settlement of Wadi Umm el-Ashdan, the reconstruction of the anthropogenic environment that allowed agricultural production suggests considerable capacities for the cultivation of trees (fig, palm), shrubs (grapevine), cereals (barley) and vegetables/legumes were achieved. The overall increase of biomass, attained by the water and soil harvesting systems utilized, not only provided the food supply for the inhabitants but also increased the available fuel, since agricultural residues of any kind can be burnt.

The investigation of available fuels and the ethnoarchaeological study of modern kiln sites in the western delta suggests that fuel choice today is also rather random and subject to the varying supply of seasonal agricultural wastes, as well as to the natural vegetation available in the surroundings. The disadvantages of this kind of mixed fuel (being of lower calorific potential), compared to a homogeneous one, can be compensated by more efficient kilns or by limiting the kind of pottery to be fired. The up-draught kilns found in the Eastern Marmarica had a high thermal efficiency. Their design made the control of the firing atmosphere far less problematic, and high temperatures could easily be reached (cf. Bourriau, Nichelson & Rose 2000). Furthermore, the ceramics produced (common wares and transport amphorae) did not need to be fired in an oxidizing/reducing atmosphere, so that exact temperatures and specific proportions of oxygen and carbon monoxide in the firing chamber do not have to be managed.

The varying fuel material, sometimes of inferior quality and lower calorific value, suited the production process and products of the Marmarican workshops. The problem of how to fire a kiln in an environment deficient in wood seems to have been overcome through a variety of sources, and sufficient amounts of fuel were in fact at hand for potters and other fuel consumers in the Eastern Marmarica (Leitch, this volume).

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Notes

1 We base the calculations here on a lower yield than in Vetter, Rieger & Nicolay (2009, 20), where the supposed average yield is taken from numbers of recent crops.

2 We are deeply indebted to Prof. Ursula Thanheiser (VIAS, University Vienna), who participated in our project in 2009. She came to this remote region, which offers few botanical remains, with truly scientific curiosity. She made the botanical analyses on location. Andreas G. Heiss (VIAS University Vienna) provided the photographs. Other samples were sent to the IFAO, Cairo, and analysed by Dr. Ahmed Fahmy, to whom we are deeply grateful. For analysing the wood samples with a high degree of competence we express our gratitude to Dr. Victoria Asensi Amorós (Xylodata Paris).

3 See Note 2.

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Abbreviations:
IFAO: Institut Français d'Archéologie Orientale
CEAlex: Centre d'Études Alexandrines

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Fuel and Fire in the Ancient Roman World

The study of fuel economics in the Roman, or indeed in any ancient world, is at a pivotal point. New research in archaeological science, the ancient economy, the ancient environment, and especially, the increasing collection of bio-archaeological datasets, are together providing a greatly enriched resource for scholars. This volume makes a first attempt to bridge the gap between 'top-down' generalized models about Roman energy consumption with the 'case study' detail of archaeological data in the Mediterranean. The papers here are the work of scholars from a variety of disciplines: from archaeobotanists and historians to archaeologists specialising in social, technical and economic fields. A more nuanced view of the organization of the social and industrial structures that underpinned the fuel economy arises. Although focused on the Roman period, some papers extend beyond this era, providing contextual relevance from the proto-historic period onwards. Much exciting interdisciplinary work is ahead of us, if we are to situate fuel economics more clearly and prominently within our understanding of Roman economics, and indeed the ancient Mediterranean economy.

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