WINE OF EGYPT'S GOLDEN AGE: AN ARCHAEOCHEMICAL PERSPECTIVE*

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Neutron Activation Analysis and selective organic contents analysis were carried out for a group of 50 Malkata wine, honey, 'ale', *ben*-oil, and meat ostraca, together with seven additional New Kingdom reference samples from Thebes. Most of the ostraca and all of the reference samples form a tight chemical group, indicating that they were most likely made of a Theban marl clay and thus produced locally, perhaps in a royal workshop. Although the contents of amphoras were generally stated to have been produced elsewhere, they were evidently imported, 'rebottled', and then sealed and registered at a central facility in Thebes. The uniform procedures that were followed and the fact that most vessels were used only once may reflect the special circumstances for which they were intended—the *heb-sed*. Organic analyses confirmed the presence of wine for the wine ostraca; a tree resin, either terebinth or myrrh, was also added as a preservative, besides masking any offensiveness.

New Kingdom Egypt was a period of remarkable internationalism and cultural development,[1] reaching its highpoint during the long reign of Amenhotep III (*c.* 1391/1383–1353/1345 BC).[2] The extensive palace complex of this pharaoh in south-western Thebes, known as Malkata (Arabic 'the place where things are picked up'), was largely excavated by the Metropolitan Museum of Art's Egyptian Expedition between 1910 and 1920.[3] Several royal palaces, upper and lower class dwellings, and other facilities (storerooms, workshops, kitchens, etc.) were uncovered over a *c.* 500 by 700 m area (fig. 1).

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[1] E.g. N. Grimal, *A History of Ancient Egypt*, trans. I. Shaw (Oxford, 1992), 199–308; M. S. Drower, 'Syria, *c.* 1550–1400 B.C.', in *CAH*³ II.1, 417–525; C. Aldred, *Akhenaten: King of Egypt* (London, 1988).

[2] Egyptian dynastic dates are according to the 'high' and 'low' options of K. A. Kitchen, 'The Basics of Egyptian Chronology in Relation to the Bronze Age', in P. Åström (ed.), *High, Middle or Low?*, I (Gothenburg, 1987), 40–3, 47, table 4; also see the supplement to the colloquium, K. A. Kitchen, 'Supplementary Notes on "The Basics of Egyptian Chronology"', in P. Åström (ed.), *High, Middle or Low?*, III (Gothenburg, 1989), 153.

[3] H. E. Winlock, 'The Work of the Egyptian Expedition', *BMMA* 6 (1912), 184–90, and 'The Egyptian Expedition 1914–15: II. Excavations at Thebes', *BMMA* 10 (1915), 253–6; A. Lansing, 'The Egyptian Expedition 1916–17: Excavations at the Palace of Amenhotep III at Thebes', *BMMA* 13 (1918), 8–14; W. C. Hayes, 'Inscriptions from the Palace of Amenhotep III', *JNES* 10 (1951), 35–56, 82–111, 156–83, 231–42; also see W. S. Smith, *The Art and Architecture of Ancient Egypt*² (revised by W. K. Simpson; Harmondsworth, 1981), 282–95, 459, nn. 3–4 (with bibliography).

An audience pavilion, where the king appeared on a balcony before the populace on major holidays, and a temple to the principal Theban god, Amun, were located to the north. More recently, the large artificial lake or harbour on the east, Birket Habu, some smaller structures of the complex, and additional buildings to the south have been excavated by the University of Pennsylvania Museum expedition.[4]

Among the many outstanding finds from Malkata, approximately 1400 jar shoulder sherds with black-inked hieratic inscriptions (hereafter 'ostraca'; see pl. XIII, 1–3), now in the Metropolitan Museum's Egyptian art collection, shed light on goods supplied to Amenhotep III's palace, including wine, 'ale', meat, fat, various oils, milk, honey, incense, and fruits.[5] Most of the ostraca belong to the last decade of Amenhotep III's reign and state that the vessels are for the '*sed*-festival of His Majesty' in the Years 29/30, 33/34, and 37/38. The *heb-sed*, which included rites and feast days, was carried out during several months overlapping two regnal years, at intervals to ensure a monarch's survival in later life and the country's welfare. Reflecting relatively more activity in certain areas of the palace and temple complex, the Year 30 and Year 37 ostraca were concentrated in the southern, older wing (extending from the West Villas to the South Palace and including the rubbish mounds on the south), while those of Year 34 were recovered from rubbish heaps in or near the forecourt of the Amun temple, which, together with a Festival Hall attached to its northern wall, had probably been specially constructed for the second *heb-sed*. A Japanese expedition that reinvestigated the main palace uncovered part of a painting mentioning 'wine for the *sed*-festival'.[6]

A large pile of sherds, including 290 ostraca with excellently-preserved meat labels, in the south-eastern corner of the forecourt of the temple of Amun implies that amphoras supplying food for the *heb-sed* feasts were most often used only once. A single usage is also borne out by the fact that amphoras were generally opened by lopping off the sealing (see below) with the entire neck, thus making it very difficult to reuse the vessel for its original purpose.[7] In contrast, amphoras employed in the day-to-day functioning of the palace in non-*heb-sed* years had been reused more often, as shown by multiple inscriptions mentioning different years and/or goods (e.g. the undated honey inscription written over a wine inscription of Year 9—see Appendix 1 **35**).[8]

[4] B. J. Kemp and D. O'Connor, 'An Ancient Nile Harbour, University Museum Excavations at the "Birket Habu"', *The International Journal of Nautical Archaeology and Underwater Exploration* 3 (1974), 101–36; C. A. Hope, *Excavations at Malkata and the Birket Habu 1971–1974: Jar Sealings and Amphorae of the 18th Dynasty: A Technological Study* (Warminster, 1977) (subsequently Hope, *Malkata Sealings*); M. A. Leahy, *Excavations at Malkata and the Birket Habu 1971–1974: The Inscriptions* (Warminster, 1978) (subsequently Leahy, *Malkata Inscriptions*).

[5] See Hayes, *JNES* 10, for find-spots, translations, and historical importance of the amphora ostraca. Although strictly inaccurate, the term 'ostraca' is used here for convenience. An additional 245 ostraca from the University of Pennsylvania Museum excavations are extensively discussed in Leahy, *Malkata Inscriptions*. The latter, from an area south of the Metropolitan excavations, are primarily wine dockets dating to the first *sed*-festival.

[6] S. Nishimoto, 'Notes on the Wall Fragments Bearing the Inscription "irp" (wine) Found from Malkata Palace', *Bulletin of Science and Engineering Research Laboratory, Waseda University* 131 (1991), 9–13; also see Group for Publishing Papers in Honor of Professor Watanabe Yasutada on the Occasion of His 70th Birthday (ed.), *Studies on the Palace of Malqata: Investigations at the Palace of Malqata, 1985–1988* [Japanese] (Tokyo, 1993), 89–98, fig. 2-2-4.3, pl. 6d.

[7] Hope, *Malkata Sealings*, 8; C. A. Hope, 'The Jar Sealings', in A. el-Khouli et al., *Stone Vessels, Pottery and Sealings from the Tomb of Tutankhamun* (Oxford, 1993), 132 (subsequently Hope, 'Tutankhamun Sealings').

[8] Also see Hayes, *JNES* 10, 39–40, and Hope, 'Tutankhamun Sealings', 132–3, n. 109.

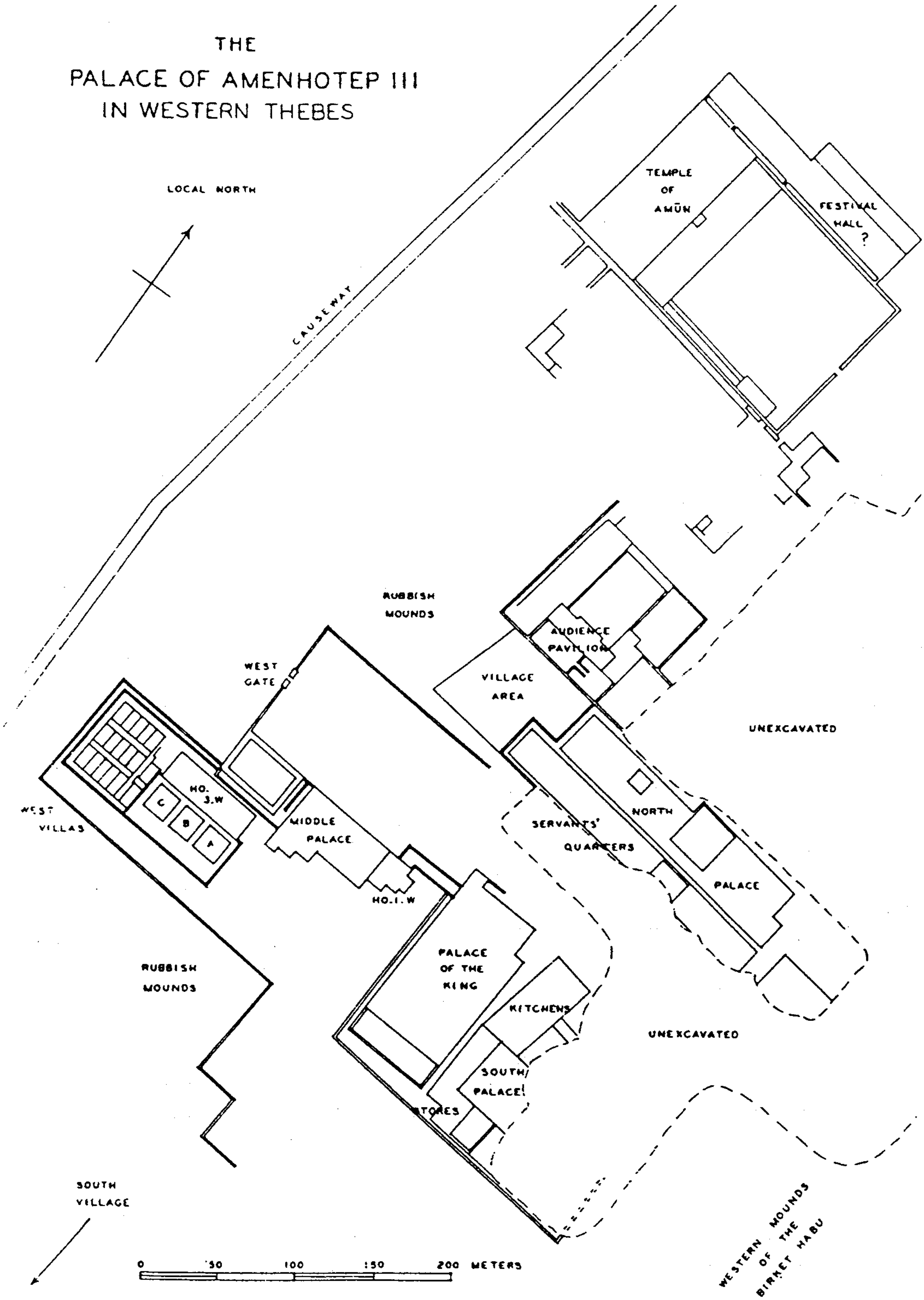


FIG. 1. Plan of Malkata, the palace of Amenhotep III, in western Thebes. The Middle Palace is also called Ho.2.W in the field records. (after Hayes, *JNES* 10, fig. 1; courtesy of the Metropolitan Museum of Art).

Wine ostraca, which comprise twenty per cent of the total corpus (285 examples), provide valuable information on wine production, shipment, and use in New Kingdom Egypt. As on a modern wine label, the ostraca (see Appendix 1) state one or more of the following items:

1. The regnal year that the beverage was presented to the pharaoh, presumably the same year it was produced. Years 30, 34, and 37 stand out in having a large number of examples, but the intervening years of the last decade of Amenhotep III's reign are also well represented.
2. The commodity itself, *irp*, perhaps deriving from the onomatopaeic response to drinking too much or too quickly.
3. Its quality: 'genuine' (Appendix 1 **25** and **27**), 'good' (**8** and **33**), 'very good' (**17**, **29–30**), etc.
4. The purpose or occasion at which it is presented, e.g. the 'lifting up of the year' or the New Year's celebration (**25**) and the *heb-sed* (**2**).
5. The geographic region where the wine was made: the 'Western River', the north-western Nile Delta region, is represented 68 times (e.g. **1**, **5**, **9–10**, **18–21**, and **27**), along with Per-hebyt in the central Delta (**11**), Tjaru (= Sile) in the north-eastern Delta (**29–31**), Memphis (**22**), the western desert oases (**4**, **16**, and **28**), possibly Syria (Kharu) (**32**), and perhaps other areas.
6. The estate or vineyard, including those of Nebmaatre, the prenomen of Amenhotep III, of Amenhotep, or simply of the pharaoh (**1**, **6–7**, **18**, **24**, and **27**), and of the Royal Wife (**3**). Labels ending with 'is-the-Splendour-of-Aten' (**5** and **20–1**) refer to a religious establishment of the pharaoh.
7. The name and/or title of the person contributing the wine: the overseer of the treasury (**13–15**; pl. XIII, 1), overseer of the fortress Thutmose (**32**), the royal scribe Huy (**33**), etc. When estates of a royal personnage or high official are mentioned (including those in **6**), it is not always clear whether the wine is a donation *of* that estate or is actually produced there and comes *from* it.
8. The chief vintner, who can be named, such as Amen[hotep] (**35**), Amenemone (**9–10**), Pa (**27**), *Nh* ... (**18**) and Ptahmai (**21**), or go unnamed (**5** and **22**).
9. Rarely, the vessel's volume is included (e.g. **24–5**). Various measures (*hin*, *min*, and *hekat*) are used on the jars, often inconsistently.[9]

The Malkata ostraca were an archaeochemist's dream come true—here were fragments of ancient vessels whose date of manufacture, place of origin, and contents were known. Besides providing an unparalleled analytical touchstone for uninscribed vessels, an independent assessment of the place of origin of the amphoras and what they contained, using sensitive chemical and statistical methods, promises to refine, extend, and perhaps modify the existing understandings about the wine amphoras and related vessels.

[9] Hayes, *JNES* 10, 95.

Analytical corpus

Vessel types, stoppering and sealing

The 35 wine ostraca that were chemically analysed were selected to be broadly representative of the wines delivered to Malkata during the last decade of Amenhotep III's life. All of the major geographic regions, and many of the named estates, officials, and chief vintners, are mentioned in their inscriptions. In addition, jars containing other goods, either believed to be produced locally (meat and beer) or imported ('ale' and *ben*-oil) and relevant to fermented beverage production, were tested.

The pottery vessels from which the ostraca come are almost exclusively amphoras of the well-known 'Canaanite jar' type.[10] The piriform-shaped jar with two handles, a pointed or knobbed base, and a narrow mouth (cf. fig. 2; pl. XIII, 2) derives from a Middle Bronze Syro-Palestinian prototype that soon made its way to Egypt and was produced there.[11] It was well-suited to transporting liquid goods by sea: its curved base was stronger than a flat base and served as a 'third handle' for loading and unloading from ships; its overall shape enabled efficient storage in a ship's hold by intercalating layers of amphoras;[12] and its usual volumetric capacity of 30 litres was close to the maximum that could be handled by a single man. As storage containers, amphoras could be rested upright against a wall or supported in a hole or a special support. Narrow mouths were stoppered and sealed by fashioning wet clay around an inserted reed, leaf, or clay bung and/or pottery sherd and the rim of the amphora (cylindrical type).[13] In some cases, although for none of the Malkata sealings, holes were punched through the sealings or even the vessel sidewalls, which may have served as secondary fermentation locks, and then resealed.[14] The king's cartouches and a shortened version of the ostracon information in Egyptian hieroglyphs, usually mentioning the wine's quality, purpose, geographic or estate origin, were stamped and/or painted on the top and sides of the stopper.[15]

[10] V. R. Grace, 'The Canaanite Jar', in S. S. Weinberg (ed.), *The Aegean and the Near East: Studies Presented to Hetty Goldman on the Occasion of Her Seventy-fifth Birthday* (Locust Valley, NY, 1956), 80–109; B. G. Wood, 'Egyptian Amphorae of the New Kingdom and Ramesside Periods', *Biblical Archaeologist* 5 (1987), 75–83; C. A. Hope, *Pottery of the Egyptian New Kingdom: Three Studies* (Burwood, 1989) (subsequently Hope, *Three Studies*); A. Leonard, Jr., '"Canaanite Jars" and the Late Bronze Age Aegeo-Levantine Wine Trade', in P. E. McGovern et al. (eds), *The Origins and Ancient History of Wine* (Luxembourg, 1995), 233–54.

[11] P. E. McGovern and G. Harbottle, '"Hyksos" Trade Connections between Tell el-Dabʿa (Avaris) and the Levant: A Neutron Activation Study of the Canaanite Jar', in E. Oren (ed.), *The Hyksos: New Historical and Archaeological Perspectives* (University Museum Monograph 96; Philadelphia, 1997), 141–57 (subsequently McGovern and Harbottle, 'Hyksos'). A more detailed monograph on the Syro-Palestinian pottery types found at Tell el-Dabʿa—both imported and locally made—is now in press: P. E. McGovern, *The Foreign Relations of the 'Hyksos': A Neutron Activation Study of the Middle Bronze Age Pottery from Tell el-Dabʿa (Ancient Avaris)* (Österreichische Akademie der Wissenschaften, Vienna). Only the round-shouldered type (fig. 2a) was made of Egyptian clays in large numbers during the New Kingdom (Hope, *Three Studies*, 92 ff), whereas flatter-shouldered varieties and generally lower necked varieties (e.g. fig. 2b–c) were more commonly produced in the Levant.

[12] Compare the Uluburun shipwreck: C. Pulak, 'The Bronze Age Shipwreck at Ulu Burun, Turkey: 1985 Campaign', *AJA* 92 (1988), 1–37, and G. F. Bass et al., 'The Bronze Age Shipwreck at Ulu Burun: 1986 Campaign', *AJA* 93 (1989), 1–29.

[13] Hope, *Malkata Sealings*, 14 f, fig. 8a; Hope, 'Tutʿankhamun Sealings', 93–5, fig. 1.

[14] A. Lucas and J. R. Harris, *Ancient Egyptian Materials and Industries*[4] (London, 1962), 19–20 (subsequently *AEMI*); L. H. Lesko, *King Tut's Wine Cellar* (Berkeley, 1977), 20; Hope, *Malkata Sealings*, 7; cf. Hope, 'Tutʿankhamun Sealings', 135.

[15] Hayes, *JNES* 10, 156–62, fig. 24.FF and GG; Hope, *Malkata Sealings*, 24–5, and Hope, 'Tutʿankhamun Sealings', 96, 132.

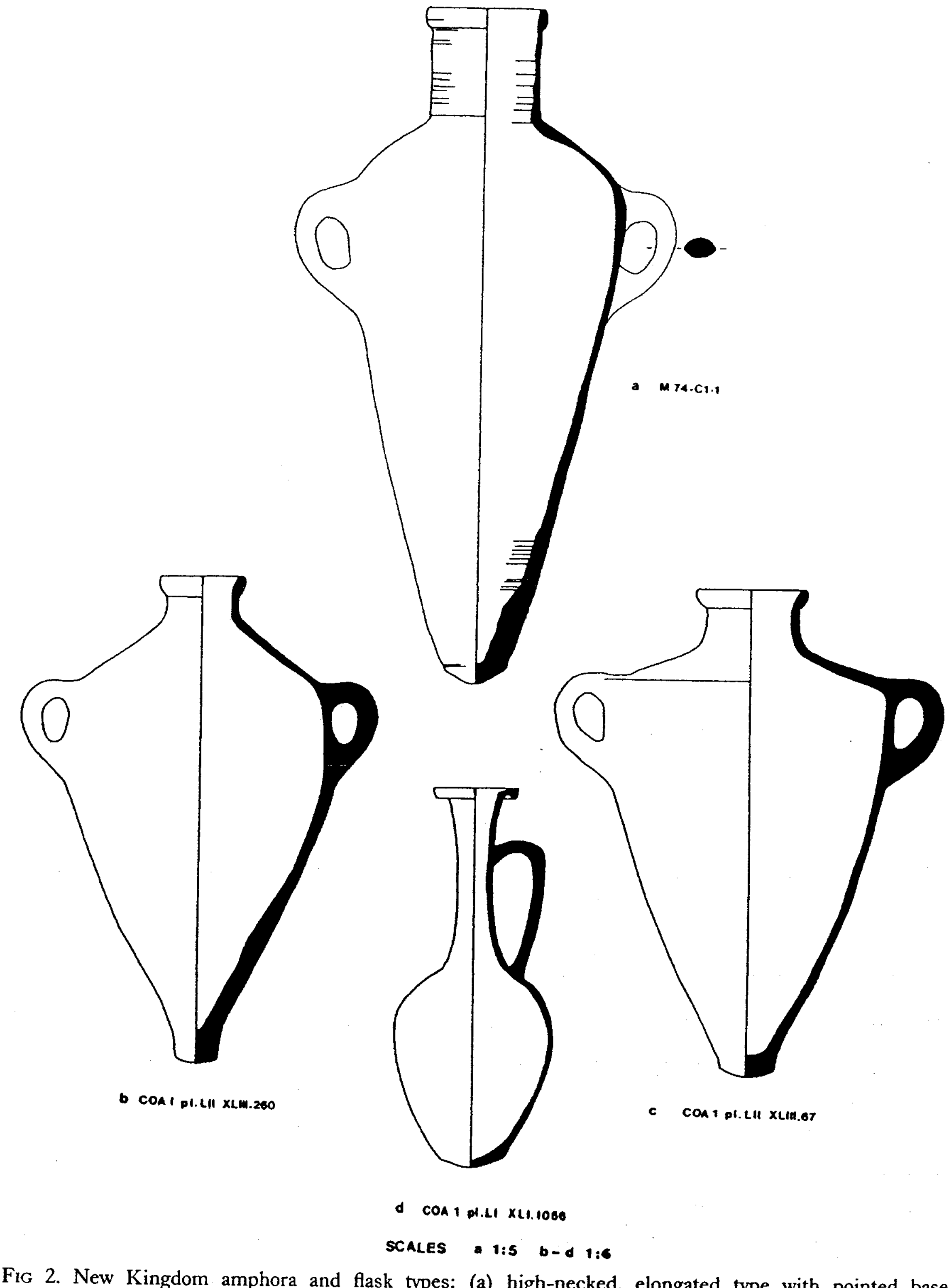


FIG 2. New Kingdom amphora and flask types: (a) high-necked, elongated type with pointed base (University of Pennsylvania Museum expedition no. M74.C1.1); (b) ovoid type with knob base (*City of Akhenaten* I, pl. 52.xliii.260); (c) shouldered type with knob base (ibid., pl. 52.xliii.67); (d) 'Syrian flask' type (ibid., pl. 52.xli.1056) (after Hope, *Malkata Sealings*, fig. 1; courtesy of Aris and Phillips Ltd).

The Malkata amphoras were constructed of hand-formed and wheel-made pieces, which were roughly smoothed on the exterior.[16] Their bases were generally made of a clay slab formed in a mould. Rims were made by folding the mouth to the exterior, thereby creating a rounded bulge that the clay sealing would adhere to better. Handles were added after drying. By contrast, Syro-Palestinian Late Bronze amphoras are both wheel-made and coil-built, with either slab bases or bases that were cut off the wheel and then plugged or closed in the upside-down mode.[17] The Late Bronze II variety (*c.* 1400–1200 BC; fig. 2b–c) is characterized by a knob base, flat shoulders, low neck, and more angular body. The latter features were rarely imitated in Egyptian native clays.[18]

The jars examined in this study were generally not decorated. Ten amphoras were covered with a white slip (Appendix 1 **2**, **8**, **10** and **31–2**), which was sometimes irregularly hand-burnished (**28–30**, **33**, and **35**). Such treatment helps to make the vessels more impervious to leakage and has the additional benefit for wine that less oxygen is available to allow *Acetobacter* bacteria to multiply and convert alcohol to vinegar.[19] Many of the other amphoras in the corpus had a whitish cast on their exterior surfaces, which has sometimes been identified as a slip but is more likely due to salts in the calcareous marl clays (see below) migrating to the surface during the drying process. Painted decoration in the analytical corpus was limited to a red-painted potter's mark (**8**), an X with horizontal lines connecting the upper and lower arms, of uncertain significance. Rarely, Malkata amphoras have multicoloured painted floral and geometric designs.[20]

Another Malkata vessel type used for transporting and storing wine was a one-handled elongated jug, belonging to the class of so-called 'Syrian flasks' (cf. fig. 2d).[21] Hayes[22] assigned the ostraca from the western oases (**4** and **28**) to this type, but his conclusion could not be corroborated because of the small sizes of the sherds. In Tutankhamun's tomb, seven such flasks were recovered, one of which was reported to contain 'dried [wine] lees' and another of which had an intact sealing that was stamped with a wine label.[23] This type is probably not represented in the analytical group.

Fabrics and firing

The exterior subsurface fabric and interior surface of most amphoras was light red or red (Munsell 10R 4–6/8). One specimen (Appendix 1 **21**) had a yellowish ware, and two

[16] Hope, *Three Studies*, 13, 93; see fig. 2a.

[17] P. E. McGovern, 'Ancient Ceramic Technology and Stylistic Change: Contrasting Studies from Southwest and Southeast Asia', in W. D. Kingery (ed.), *Technology and Style* (Ceramics and Civilization 2; Columbus, 1986), 33–52; reprinted, in J. Henderson (ed.), *Scientific Analysis in Archaeology and its Interpretation* (Oxford, 1989), 63–81; W. D. Glanzman and S. J. Fleming, 'Pottery Technology: Fabrication Methods', in P. E. McGovern, *The Late Bronze and Early Iron Ages of Central Transjordan: The Baqᶜah Valley Project, 1977–1981* (University Museum Monograph 65; Philadelphia, 1986), 164–77.

[18] Hope, *Three Studies*, 15, 94–5.

[19] J. Farkaš, *Technology and Biochemistry of Wine*, I (New York, 1988), 208–14, 255.

[20] Hope, *Malkata Sealings*, 70.

[21] See R. Amiran, *Ancient Pottery of the Holy Land; From Its Beginnings in the Neolithic Period to the End of the Iron Age* (New Brunswick, NJ, 1970), 167, 170–1.

[22] *JNES* 10, 89.

[23] R. Holthoer, 'The Pottery', in el-Khouli et al., *Stone Vessels, Pottery and Sealings from the Tomb of Tutᶜankhamun*, 64–7 (subsequently Holthoer, 'Tutᶜankhamun Pottery'); Hope, 'Tutᶜankhamun Sealings', 115–16.

ostraca (**4** and **16**) were whitish in colouration. A number of examples had grey cores resulting from incomplete oxidation of elemental carbon, some of which derived from small amounts of organic temper added to the clay. Although a proper petrographic study of the Malkata wine jars is yet to be carried out,[24] previous investigators report that the fabric, designated Marl D,[25] contains large amounts of limestone temper, in addition to quartz, mica, and feldspar. Hope[26] suggests a firing temperature range of 800–850°C, based on refiring experiments. Carbonates burn out to a minimal extent and calcareous clays become relatively dense and vitrified in this range. Egyptian calcareous marls are well-suited for amphoras used in the transport and storage of food stuffs and other materials, because of their strength and non-permeability, in contrast to Nile alluvial wares.[27]

Interior residues

Six wine amphoras had red deposits of varying thicknesses on their interiors (Appendix 1 **3**, **9**, **13**, **15**, **33**, and **35**; also see pl. XIII, 1). Less commonly, the colouration of such a deposit was dark brown (**11**, **23**, and **25**) or black (**34**), the latter having a shiny, resinous character. A perusal of the collection of ostraca as a whole indicates that red and brown interior residues are more prevalent for wine than other foods or beverages. Incense (*sntr*) and resin (*sft*) amphoras also have dark brown or black deposits on their interiors.[28] No evidence was found of deliberate sealing of vessels with a resin or other material.[29] Occasional whitish patches, probably secondary calcite accumulations, and darkish, irregular modern organic growths were also noted.

Ten meat amphoras or wider-mouthed jars (Appendix 1 **38–48**), which comprise the highest percentage of ostraca (375 out of 1400—27%), were probably made locally, because of the fact that the donors were exclusively local palace or Theban officials.[30] Three additional New Kingdom ostraca, two from the Valley of the Kings in western Thebes and one from the workmen's village of Deir el-Medineh (Appendix 2), were chosen for analysis because their fabric types had been identified as Marl D, possibly of local origin. Two other early Eighteenth Dynasty Theban jar ostraca from the Embalmer's Cache (pit 1017) of the Sankhkare cemetery were designated as Marl C, and an early Eighteenth Dynasty canopic jar of Marl B and a Middle Kingdom tall cylindrical jar of Marl A2 from tombs in the hills of the Asasif and Sheikh Abd el-Qurneh were thought to be sufficiently unique to have been produced locally.[31] *In toto*, the meat and additional Theban ostraca and early Eighteenth Dynasty pottery from Thebes were chosen to

[24] P. W. Nicholson has sherds from the same ostraca that have been analysed by NAA, and is planning such a study.

[25] Egyptian pottery is classified macroscopically and sub-microscopically (up to 25 × magnification) according to the so-called Vienna System (H.-Å. Nordström, 'Ton (clay)', *LÄ* VI, 630–4; H.-Å. Nordström and J. Bourriau, 'Ceramic Technology: Clays and Fabrics', in Do. Arnold and J. Bourriau (eds), *An Introduction to Ancient Egyptian Pottery* (Mainz, 1993), 143–90 (subsequently Nordström and Bourriau, 'Ceramic Technology'); cf. Hope, *Malkata Sealings*, 66–9, particularly fabric BaI.

[26] *Malkata Sealings*, 67.

[27] Hope, *Three Studies*, 98, n. 13.

[28] Hayes, *JNES* 10, 95.

[29] Cf. Hayes, *JNES* 10, 96; *AEMI*[4], 19–20; Hope, *Three Studies*, 98, n. 14.

[30] Hayes, *JNES* 10, 91–2.

[31] Dorothea Arnold, personal communication.

provide a good chemical reference group for Theban New Kingdom pottery, since samples of the locally available modern clays are yet to be collected and tested. As will be seen in what follows, the chemical composition of the local Theban clay is critical in determining the origin(s) of the wine jars.

One ostracon (**37**) of a large group (298 examples) and possibly a second (**28**) were said to contain *srmt*, either 'ale' (to be distinguished from everyday 'beer', *ḥnqt*)[32] or a solid material, deriving from dates[33] or other materials used in barley beermaking.[34] *Ben*-oil (*bꜣq*), which is generally understood to refer to the seed oil of the moringa tree,[35] occurs on two ostraca (**32** and **36**).

Archaeochemical methods and results

The physico-chemical method of Neutron Activation Analysis (NAA) has been extensively employed in pottery provenance studies, because of its sensitivity and precision in measuring as many as 35 elements, including rare earths which often characterize a clay source, and because it requires very small samples (50–200 mg) that are non-destructively analysed. The chemical composition of the 54 ostraca, detailed in Appendices 1–2 and in Tables 1–5, was determined by NAA at the University of Missouri Research Reactor.[36]

Samples were prepared by scraping the surface with a sapphire tool until the interior fabric was exposed. After soaking in deionized water and crushing the specimens to a fine powder using an agate mortar and pestle, the samples were oven-dried at 85°C. Two portions of about 75–100 mg and 200 mg were subjected to short and long irradiations respectively. The resultant gamma ray data was then processed, incorporating decay corrections, spectrum analyses, and standards, yielding concentrations of 30 elements for each specimen (Tables 1–5).

Relating the chemical composition of a particular ancient pottery sample to a given clay source, thereby 'fingerprinting' the pottery and its presumed place of manufacture, is based on what has become known as the Provenience Postulate,[37] in which it is assumed that the chemical variation within a given clay source is less than that between different sources. The inclusions in the Malkata pottery, whether deriving from the original clay or added as temper by the potter, are relatively 'pure' (e.g. quartz, calcite, and organic materials) and have a diluent effect on the chemical composition of an ancient sample which is spread across the range of elements.

[32] Hayes, *JNES* 10, 90; Leahy, *Malkata Inscriptions*, 5–13.

[33] W. Helck, *Materialen zur Wirtschaftsgeschichte des Neuen Reiches*, IV–V (Akademie der Wissenschaften und der Literatur, Abhandlungen des Geistes- und Sozialwissenschaftlichen Klasse; Mainz, 1963–4), 691–2 (495–6) and 792–3 (184–5).

[34] See Leahy, *Malkata Inscriptions*, 5–6, n. 9; D. Samuel, 'Archaeology of Ancient Egyptian Beer', *Journal of the American Society of Brewing Chemists* 54 (1996), 3–12.

[35] Hayes, *JNES* 10, 93, and Leahy, *Malkata Inscriptions*, 17–18; cf. L. E. Stager, 'The Firstfruits of Civilization', in J. N. Tubb (ed.), *Palestine in the Bronze and Iron Ages* (London, 1985), 174–5, supporting the older translation, 'olive oil' (subsequently Stager, 'Firstfruits').

[36] For analytical procedures, see M. D. Glascock, 'Neutron Activation Analysis', in H. Neff (ed.), *Chemical Characterization of Ceramic Pastes in Archaeology* (Madison, 1992), 11–26.

[37] P. C. Weigand et al., 'Turquoise Sources and Source Analysis: Mesoamerica and the Southwestern U.S.A.', in T. K. Earle and J. E. Ericson (eds), *Exchange Systems in Prehistory* (New York, 1977), 15–34.

The author is presently involved in a large NAA study of Middle Bronze Age pottery from the Levant, including 578 pottery and clay samples from the key site of Tell el-Dabʿa, the ancient Hyksos capital of Avaris, in the north-eastern Nile Delta.[38] To date, 119 pottery and clay samples have been tested from sites in Middle and Upper Egypt, including Kahun and Dahshur near Lisht, Tell el-Amarna, and Abydos, which range in date from the Old to the New Kingdom. An additional 760 pottery and clay samples from 55 coastal and inland sites of Syria, Lebanon, Jordan, and Israel, including Ras Shamra (ancient Ugarit), Tell Kazel, Hama, Byblos, Sidon, Kamid el-Loz, Megiddo, Tel Aphek, Jaffa, Ashkelon, Tell el-ʿAjjul, Tell Beit Mirsim, Beth Shan, Pella, Jericho, Tell el-Fukhar, the Baqʿah Valley of Transjordan, and Bab el-Dhraʿ, have also been analysed. Other projects,[39] accounting for 1208 pottery and clay samples from 79 more Egyptian and Levantine sites, complete the databank for this region.

The clays which have thus far been analysed date from the Lower Cretaceous Period to recent times and derive from deposits throughout the Levant and Egypt. Egyptian alluvial and marl clays, red loess clays of the southern Palestinian coastal region, yellow limestone-derived clays of the Palestinian hill country, Transjordanian smectites and kaolin clays, and other clay sources are well represented in the NAA databank. The Old World databank, altogether 5716 samples, has excellent temporal and spatial coverage of other regions of the Near East and Mediterranean, including the Sudan, Greece, Iraq, Iran, and parts of Turkey. This wide coverage, coupled with large numbers of samples for locally defined groups, enable powerful statistical techniques to be applied in determining the archaeological origin(s) of the Malkata amphoras.

A range of univariate and multivariate algorithms—means and standard deviations, and correlational, clustering, and principal components analysis of a range of elements—are used to define local chemical groups of ancient pottery, with widely divergent samples (outliers) being excluded. Archaeological and geological criteria are important in refining and testing these groups, whether well-dated pottery types, clays from specific geochemical regimes, clay beds within a single deposit, etc. This approach is essential when an ancient clay source has been totally exploited or systematic clay sampling has not yet been carried out in a region.

Clay sources of the Malkata jars according to Neutron Activation Analysis

The Old World databank was searched for the closest chemical 'matches' to the 35 Malkata wine ostraca in mean Euclidean distance (MED) space (defined as the square root of the mean of the sum of the squares of the differences between the log elemental concentrations of any given pair of samples). Although correlational effects are excluded from this calculation, excellent results can be obtained with the fifteen elements—sodium (Na), potassium (K), caesium (Cs), rubidium (Rb), barium (Ba), scandium (Sc), europium (Eu), thorium (Th), hafnium (Hf), manganese (Mn), cobalt (Co), chromium (Cr), iron (Fe), samarium (Sm), and ytterbium (Yb), as the oxides—because the variance in the MED approaches zero as the inverse of the number of

[38] M. Bietak, *Avaris and Piramesse: Archaeological Exploration in the Eastern Delta*[2] (London, 1986), 'Egypt and Canaan during the Middle Bronze Age', *BASOR* 281 (1991), 27–72, and *Avaris, The Capital of the Hyksos* (London, 1996); see also n. 11 above and P. E. McGovern et al., 'The Archaeological Origin and Significance of the Dolphin Vase as Determined by Neutron Activation Analysis', *BASOR* 296 (1994), 31–43.

[39] E.g. M. K. Kaplan, *The Origin and Distribution of Tell el Yahudiyeh Ware* (SMA 62; Gothenburg, 1980); D. Brooks et al., 'Biblical Studies through Activation Analysis of Ancient Pottery', in C. W. Beck (ed.), *Archaeological Chemistry* (Advances in Chemistry 138; Washington, DC, 1974), 48–80.

variables. An MED of less than 0.08 has been empirically determined to be indicative of group membership and a chemical 'match'.

Except for four examples, all the wine ostraca (Table 1, NAA nos. PMG228, 248–57, and 260–78, and 332–3) are closest to one another in an MED range from 0.02 to 0.08, averaging 0.035 for the next nearest specimen and with 26 samples being within 0.02–0.04 of one another. No other samples in the databank, representing other geographic regions of Egypt and the Eastern Mediterranean, were as close as those from Malkata itself. Similarly, the ten meat ostraca (PMG335–9 and 341–5), two probable 'ale' specimens (PMG326 and 334), and seven additional Theban samples (Table 2, PMG327–9, PMG447–8, PMG450, and PMG455; see pp. 76–7) belonged to the same group, which is characterised by very small group standard deviations (5–15% of the mean) for individual elements (except the alkalis and alkaline earths, nickel, antimony, arsenic, and strontium). Marl D, the fabric that has been identified as most commonly used for amphoras in New Kingdom Egypt on the basis of macroscopic and low-power microscopic criteria (above), thus has a firm chemical basis. Moreover, the uniqueness of some samples in this group and the likelihood that the Malkata amphoras were specifically made to 'rebottle' special goods for the *heb-sed*, as argued in the concluding section of the paper, are strong indicators that the ancient clay which was exploited was located in the Theban area.

It is common for the elements in clays and minerals to covary with one another. For example, the high correlation ($r>0.99$) of iron and scandium, both trivalent ions of about equal size, in nature is well known. Univariate statistics can be very misleading if such relationships go unrecognised.

If the variance–covariance matrix for many elements of a presumed local group is calculated, a new set of standardised orthogonal coordinates (eigenvectors) can be defined in multidimensional Mahalanobis space that takes advantage of elemental correlations.[40] For the statistical calculations, the oxide data are converted to logarithms, since many chemical elements appear to be lognormally distributed in nature, and are also standardised by this procedure. The Mahalanobis distance of a given sample from the origin or centroid of the group is directly related to the probability of the group membership of that sample, assuming a multivariate normal distribution.[41] Using fifteen elements in the calculation, it has been estimated by comparisons of the large Brookhaven New World pottery databank (about 10,000 samples) against the Old World databank (about 5000 samples) that the accidental assignment of a sample at a Mahalanobis distance probability (MDP) of 1% is nil for these two archaeologically and geochemically distinct regions.[42] Within a more circumscribed region, such as Egypt and the Eastern Mediterranean, where the same or related geological processes have been at work, this unique chemical 'fingerprinting' is not assured, but with high correlations between many elements, such as is characteristic of Levantine clays and pottery, it is possible to achieve extremely good results. An MDP above 5% for a sample tested against a group with a high sample number to variate ratio is a strong guarantee that it belongs to that group.

Using the same fifteen elements used to determine the MED and not correcting for dilution or concentration effects, the average Mahalanobis distance of the presumed Theban local marl group (Tables 1 and 2) was calculated to be 72.8%, well above the 5% cut-off point. Indeed, 27 of the presumed local Theban samples exceeded 85%, and all other samples in the Old World databank, totalling 5716 examples, had a 0% MDP of belonging to the group. It is virtually certain therefore that the Malkata and additional Theban samples were made from the same marl clay, probably of local origin.

Of the four wine ostraca that did not belong to the local Theban group, one specimen (Appendix 1 **8**; Table 5, PMG259) is of uncertain origin but closest to several samples in the local

[40] G. Harbottle, 'Efficiencies and Error-Rates of Euclidean and Mahalanobis Searches in Hypergeometries of Archaeological Ceramic Compositions', in E. Pernicka and G. A. Wagner (eds), *Archaeometry* 90 (Basel, 1991), 413–24 (hereafter Harbottle, 'Efficiencies').

[41] E. V. Sayre, 'Brookhaven Procedures for Statistical Analyses of Multivariate Archaeometric Data', unpublished Brookhaven National Laboratory Report BNL-23128 (Upton, NY, 1975).

[42] Harbottle, 'Efficiencies', 413–24.

group; it is too far removed in MED space (0.12), however, to make a positive assignment. A second specimen (**34**; Table 3, PMG253), which refers to the enigmatic 'child of the nursery *Kmi*', is within 0.04–0.08 MED of numerous Nile alluvial specimens in the databank, and has a 14.9% MDP of belonging to the large Tell el-Dabᶜa Nile alluvial clay group (184 samples).

The two remaining non-local specimens (**4** and **16**; Table 4, PMG331 and PMG258 respectively) have labels stating that they are from a western oasis. They are also characterised by whitish fabrics. The two samples, whose chemical compositions diverge significantly from one another and from other Egyptian marls, are not 'matched' by any samples in the Old World databank. Since chemical analyses of local pottery and clays from the oases are quite limited,[43] it is possible that they were made of as yet unsampled and untested clays from this region.

Because *ben*-oil was apparently added to one of the wine amphoras (Appendix 1 **32**), the clay origin of an amphora containing this oil (**36**; Table 5, PMG340) was of interest. The vessel, whose label states that it is from the mayor of She-Sobek (probably the Fayyum), does not 'match' the locally well-defined marl clay (Marl C) which outcrops in the vicinity[44] nor any other Egyptian clay or pottery sample in the NAA databank.

Organic contents of the jars

Nine wine ostraca and one 'ale' ostracon, denoted as organic samples nos. 1–10 in Appendix 1 (see **9**, **11**, **23**, **25–6**, **32–5**, and **37**) were tested for organic compounds, specifically tartrate/tartaric acid (characteristic of grape products, including wine), oxalate (often deriving from barley and deposited as the insoluble calcium salt in vessels used for barley beer), and tree resins. Our archaeochemical laboratory employs complementary analytical techniques—infrared spectrometry (IR), liquid chromatography, and wet chemical analyses—to determine the presence/absence of these and other organics.[45]

Residue scrapings and/or extracts of small sherds from each ostracon were first analysed by diffuse-reflectance Fourier-transform IR spectrometry. This versatile technique has the advantage that very little material is required (1–10 mg) and, unlike transmission IR spectrometry, an optically transparent KBr (potassium bromide wafer) does not have to be prepared.

Organic samples 5 (Appendix 1 **34**) and 6 (**23**) had shiny black and dark brown residues on their interiors, respectively. Both were extracted with ethanol using an ultrasonicator (two 20-min periods), evaporating to dryness, and testing the extracts by diffuse-reflectance Fourier-transform IR spectrometry.[46] Organics were very likely contributed by the residue itself, which gave positive results when tested without extracting, and from material that had accumulated in the pores of the pottery fabric. On fig. 3, the maxima at 1710–1725 cm^{-1}, 1450–1460 cm^{-1}, and 1240–1255 cm^{-1} are definitive for the carbonyl and carboxylic acid groups of tartaric acid, as a comparison with the spectrum of L-(+) tartaric acid, the naturally occurring isomer (fig. 4), shows. A minor amount of tartrate, probably in the form of the calcium salt, is indicated by the medium intensity bands in the 1550–1650 cm^{-1} range. The broad absorption band centred at about 3350 cm^{-1}

[43] Compare S. K. Tobia and E. V. Sayre, 'An Analytical Comparison of Various Egyptian Soils, Clays, Shales, and Some Ancient Pottery by Neutron Activation', in A. Bashay (ed.), *Recent Advances in Science and Technology of Materials*, III (New York, 1974), 118–21, tables IV and V (subsequently Tobia and Sayre, 'Analytical Comparison'); also see R. Said, *The Geology of Egypt* (New York, 1962), 67–86, and M. Hermina, 'The Surroundings of Kharga, Dakhla and Farafra Oases', in R. Said (ed.), *The Geology of Egypt* (Rotterdam, 1990), 259–92.

[44] McGovern et al., *BASOR* 296, 40–1; Tobia and Sayre, 'Analytical Comparison', 108–12, table II.

[45] P. E. McGovern and R. H. Michel, 'The Analytical and Archaeological Challenge of Detecting Ancient Wine: Two Case Studies from the Ancient Near East', in McGovern et al. (eds), *The Origins and Ancient History of Wine*, 57–65 (subsequently McGovern and Michel, 'Two Case Studies'); R. H. Michel et al., 'The First Wine and Beer: Chemical Detection of Ancient Fermented Beverages', *Analytical Chemistry* 65 (1993), 408A–13A; R. H. Michel et al., 'Chemical Evidence for Ancient Beer', *Nature* 360 (1992), 24.

[46] A Nicolet 5DXB instrument, with a 20DX data processor, was used in taking measurements at 2 cm^{-1} resolution. Spectra were then deresolved at 16 cm^{-1} for library storage, searches, and printing.

results from hydroxyls of tartaric acid (fig. 3) and water of hydration. C–H bonds account for the intense peak around 2900 cm^{-1}, due to tartaric acid/tartrate and other organics.

The possibility of the other organic compounds having been derived from a tree resin, which was more definitively supported by the liquid chromatographic data presented immediately below, is evident from the IR spectra for myrrh (genus *Commiphora* of the Burseraceae family) and

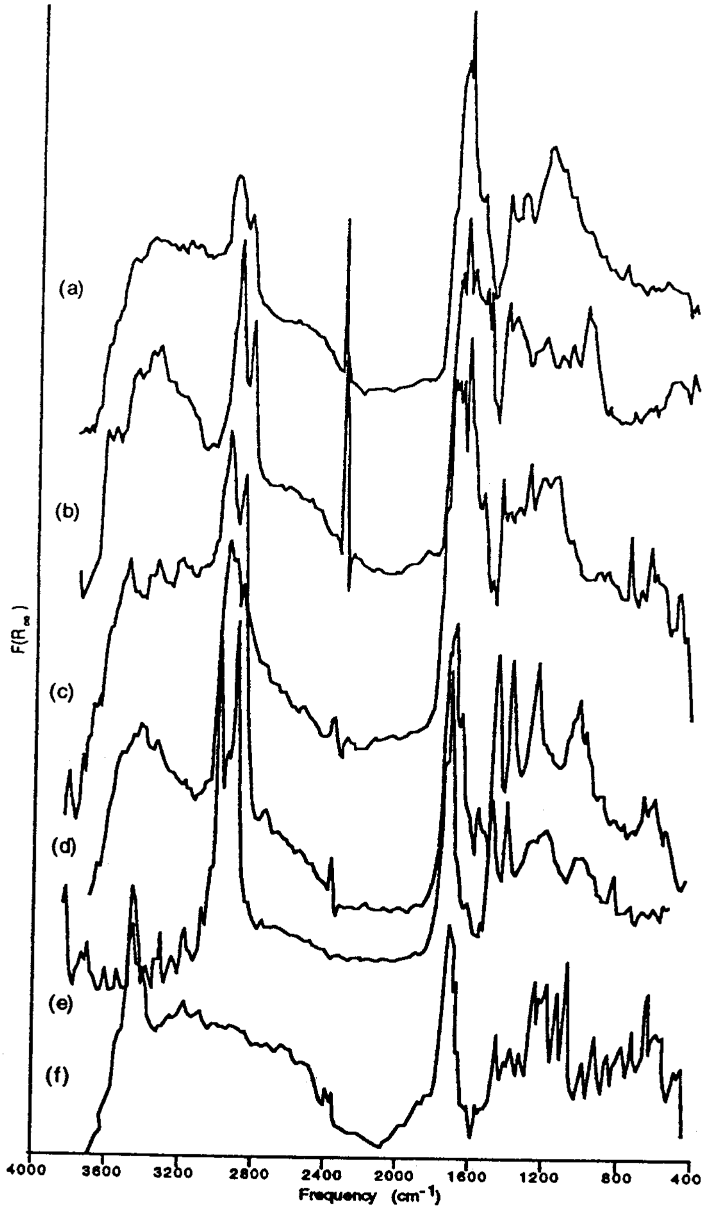


FIG 3. Diffuse-reflectance Fourier transform infrared spectra of a. organic sample 5 (Appendix 1 **34**); b. organic sample 6 (**23**); c. red lustrous spindle bottle (Royal Ontario Museum, Egyptian Dept. no. 910.85.15 (B.969)); d. Chian terebinth resin (sample from amphora KW 144, from the Uluburun shipwreck); e. commercial myrrh (uncertain origin); and f. L-(+) tartaric acid.

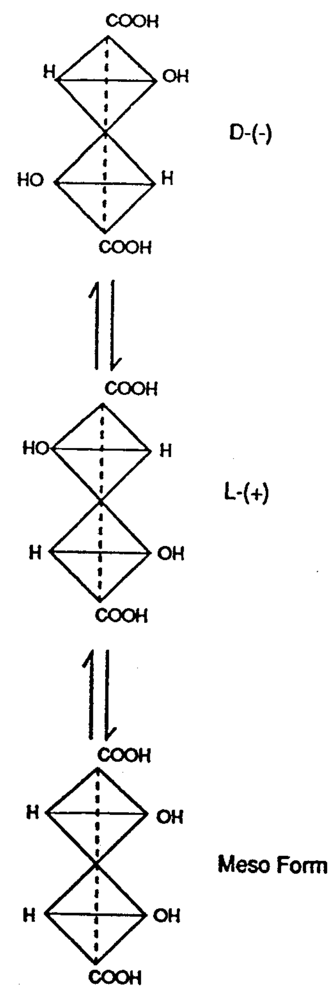


FIG 4. Stereoisomers of tartaric acid.

Chian turpentine or terebinth resin (*Pistacia atlantica* Desf.) from an amphora on the Uluburun shipwreck (sample from amphora KW 144).[47] The carbonyl peaks at 1720–1740 cm^{-1}, unfortunately, overlap with those of tartaric acid, but the intense maxima at 1460 cm^{-1}, 1380 cm^{-1}, and 1250 cm^{-1}, as well as other bands in the 'fingerprint' region from 1550 to 800 cm^{-1}, are sufficiently distinctive to posit the presence of a tree resin. Unexplained or higher intensity peaks on the spectra for Malkata organic samples 5 and 6, as contrasted with that of L-(+) tartaric acid, are very likely due to this tree resin. The IR spectrum of a dark brown deposit from a liquid that had leaked out and congealed on the surface of a sealed red lustrous spindle bottle[48] from New Kingdom Egypt is very similar to those of organic samples 5 and 6. This vessel type probably influenced the development of the more bulbous 'Syrian flask', which may have been used to transport and store some of the wine at Malkata.

An instructive exercise to substantiate that wine and a tree resin were mixed together in the Malkata wine amphoras, such as organic samples 5 and 6, is to make up hypothetical IR spectra using known constituents. On fig. 5, a mixture of 40% myrrh, 40% tartaric acid, and 20% calcium tartrate provides an excellent match for 'unknown' organic samples 5 and 6.

Six other organic samples from Malkata wine amphoras gave IR spectra in which calcium tartrate clearly exceeded tartaric acid. The IR spectra for organic samples 2 (Appendix 1 **26**) and 7 (**11**) are most definitive (see fig. 6). the sharp, intense peaks at about 1610 cm^{-1} and 1585 cm^{-1} for these two samples and calcium tartrate, which are due to the carboxylate ion, should be especially noted. Many other absorption bands (e.g. 1385, 1330, 1275, 1150, 1060, 1005, 955, and 815 cm^{-1}) in the 'fingerprint' region match up exactly and have similar shapes and intensities for the three spectra. Although a broad hydroxyl band is present, hydrocarbon peaks at around 2900 cm^{-1} are lacking on each. Organic sample 7 had a thick, dark brownish residue on its interior, whereas the deposit on organic sample 2 was thin and reddish.

Two sharp peaks in the 1580 to 1625 cm^{-1} range (fig. 7) are characteristic of the other organic samples that yielded evidence of calcium tartrate, viz. 1 (Appendix 1 **35**), 3 (**32**), 4 (**25**), 7 (**11**), and 8 (**35**). Peaks in the 'fingerprint' region above 1250 cm^{-1} also correspond to those of calcium tartrate. Other peaks below 1250 cm^{-1} are hidden under the wide absorption band (maximum of 1030 cm^{-1}) resulting from clay minerals in the residue scrapings. When relatively more clay is present, another band in the 1350 to 1500 cm^{-1} range begins to mask tartrate peaks here (compare the spectrum for organic sample 8—fig. 7). A hypothetical mixture of 70% calcium tartrate and 30% pottery fabric (from ostracon **24** made of probable Theban marl clay according to the NAA results) gave an IR spectrum that is closest to that of sample 8, with distinct carboxylate peaks around 1600 cm^{-1} (fig. 8). All of these samples had reddish or brownish residues of varying thicknesses on their interiors. Because of its small size, organic sample 9 (**39**) was not analysed by IR spectrometry.

Extracts of the eight samples that tested positive for tartaric acid/tartrate, in addition to organic sample 9, were then analysed by liquid chromatography.[49] The ultraviolet (UV) spectra of organic material, which came off the column at about 1.1, 1.3 and 1.6 min (fig. 9) substantiated the groupings, already established by IR, at a high probability level. Thus, L-(+) tartaric acid predominates in organic samples 5 and 6 (fig. 10), whereas the other Malkata samples have absorption spectra typical of calcium tartrate.

[47] See Pulak, *AJA* 92, 11.

[48] The vessel (inventory no. 910.85.15 (B.969)) was sampled by R. Shaw of the Royal Ontario Museum, Egyptian Department. It is illustrated and described in D. M. Robinson and C. G. Harcum, *A Catalogue of the Greek Vases in the Royal Ontario Museum of Archaeology, Toronto*, I (Toronto, 1930), 18, pl. vi.72–3.

[49] Samples were run at ambient temperature on a high-performance liquid chromatograph, Hewlett-Packard HP-1090, with extensive software for data handling and manipulation. Methanol extracts were passed through a 25 cm × 4.6 mm silica column at a flow rate of 2.0 ml/min, with methanol as the solvent. For samples composed primarily of calcium tartrate, as shown by the IR results, acidified samples were first prepared and dried. Ultraviolet absorptions were measured over a range from 200 to 400 nm, using detectors that were most sensitive at 210, 254, and 260 nm. Samples volumes ranged from 2.0 to 10.0 μl, depending on the concentration of organics in the unknown.

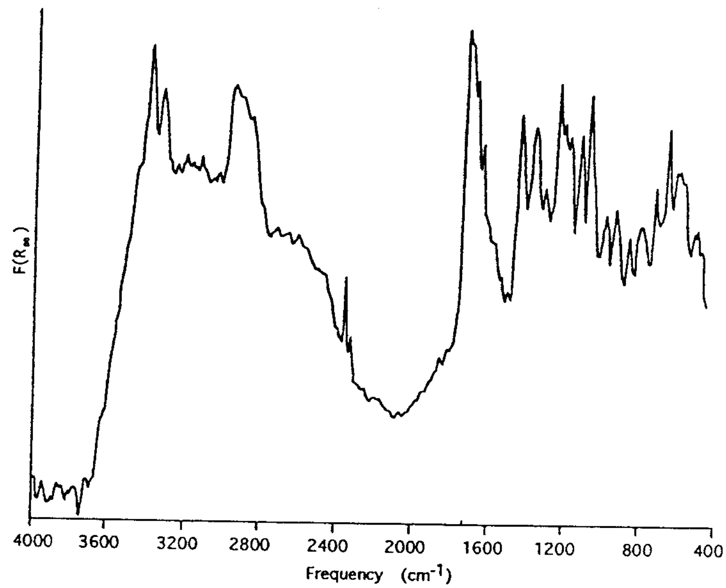


FIG 5. Diffuse-reflectance Fourier transform infrared spectra of a hypothetical mixture of 40% modern myrrh, 40% L-(+) tartaric acid, and 20% synthetic calcium tartrate.

The chromatographic evidence was more determinative than that of IR in establishing the identity of the tree resin additive to the wine. The 1.6 min spectra of organic samples 5 and 6 (fig. 11), for example, are marked by strong absorptions at 250 nm, which correlate with that of myrrh. The other Malkata samples have spectra that are most similar to that of Chios turpentine or terebinth resin (*Pistacia atlantica* Desf.). Further study, however, is needed for definitive identifications of the tree resins present in the Malkata wines.

Finally, a third analytical technique confirmed the presence of tartaric acid/tartrate, viz. a specific, wet-chemical test[50] in which β,β'-dinaphthol and concentrated sulphuric acid are used to convert tartaric acid to a compound that exhibits green fluorescence under UV light. All of the wine ostraca samples gave a positive result except organic sample 9. The liquid chromatographic data for the latter sample, in which organic material came off at 1.6–1.7 min but not at 1.3 min, indicates that it was largely comprised of terebinth resin.

A residue scraping from one of the 'ale' ostraca (organic sample 10; Appendix 1 **37**) was also tested by a specific, wet-chemical test for calcium oxalate. This compound is a principal component of 'beerstone', which settles out at the bottom and along the sides of barley beer processing and storage vesels.[51] The Feigl test,[52] in which oxalate is reduced in an acidic medium to glyoxalic acid, followed by reaction with phenylhydrazine and hydrogen peroxide, to give a distinctive pinkish red colour, was positive for organic sample 10.

The analytical results for ostraca which stated that they contained some other material besides wine and tree resin were scrutinised. No evidence of honey was found for organic sample 8 (**35**), and unless *ben*-oil is similar in composition to the tree resins in our reference group, organic sample 3 (**32**) did not differ in any significant way from the other tartaric acid/tartrate and tree resin samples.

[50] F. Feigl, *Spot Tests in Organic Applications* (New York, 1954), 384–5.
[51] Michel et al., *Analytical Chemistry* 65, 412A, and *Nature* 360, 24.
[52] Feigl, *Spot Tests*, 384–5.

Discussion and conclusions

The results of the three independent chemical analyses of organic samples 1–8 strongly support the presence of tartaric acid and/or its salt, calcium tartrate, combined with a tree resin (also including organic sample 9). Since tartaric acid/tartrate occurs in large amounts in nature only in grapes, the organic contents of the amphoras is in accord with the commodity, wine, stated on their labels.

Under normal conditions and at room temperature, grape juice easily and quickly ferments to wine. Because of slow pressing methods in antiquity and high temperatures in the Middle East, fermentation had probably begun before a jar was filled.[53] The addition of terbinth resin, myrrh, and other tree resins to wine, in the fashion of modern *retsina* (which now contains either pine[54] or sandarac resin),[55] served in part to disturb and inhibit the growth of bacteria (*Acetobacter*) that convert wine to vinegar, besides

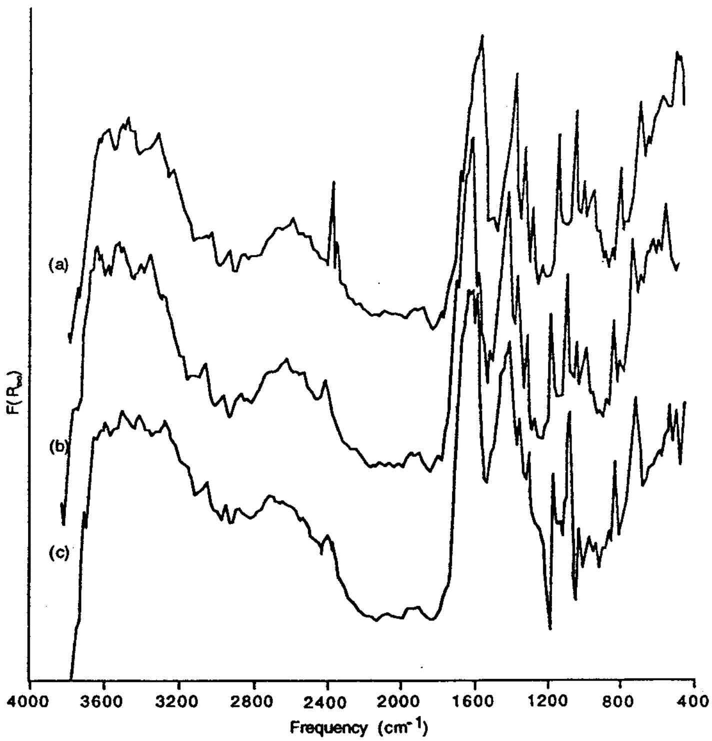


FIG 6. Diffuse-reflectance Fourier transform infrared spectra of a. organic sample 2 (Appendix 1 **26**); b. organic sample 7 (**11**); c. synthetic calcium tartrate.

[53] *AEMI*[4], 16–18.

[54] An ancient pine-resinated wine of fifth century BC Italy is chemically characterized by E. Hostetter et al., 'A Bronze Situla from Tomb 128, Valle Trebba: Chemical Evidence of Resinated Wine at Spina', *Studi Etruschi* 59 (1994), 211–25.

[55] For this resin, which derives from a north-western African tree (*Tetraclinis articulata*), see *AEMI*[4], 321, 358–9.

masking any offensiveness of taste and smell.[56] Wine and tree resins figure importantly in the Egyptian pharmacopeia, since both have anti-microbial properties.[57] Ancient Egyptians need not have had a scientific understanding of the effects of these natural products to appreciate their beneficial properties. Developing a *medicamentum* or preservative to prevent wine from spoiling must have been an important priority even before Pliny the Elder[58] and Columella[59] wrote about it in the first century AD.

Terebinth resin, which is best supported by the chemical evidence as the tree resin added to the majority of the Malkata wine jars, has been described as the 'queen of

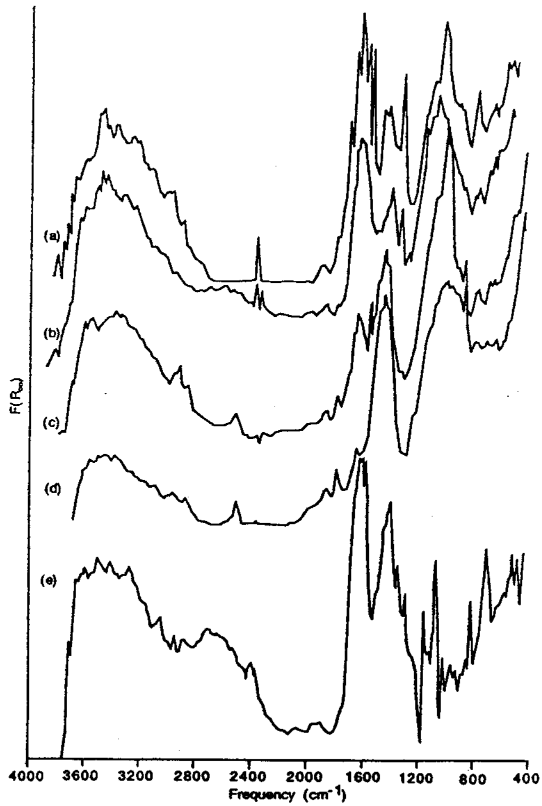


FIG 7. Diffuse-reflectance Fourier transform infrared spectra of a. organic sample 3 (Appendix 1 **32**); b. organic sample 4 (**25**); c. organic sample 8 (**35**); d. pottery fabric of **24**; e. synthetic calcium tartrate.

[56] G. Majno, *The Healing Hand: Man and Wound in the Ancient World* (Cambridge, 1975), 64, 124, 210–25; A. Tchernia, 'La vinification des romains', in G. Garrier (ed.), *Le vin des historiens: Actes du 1er symposium vin et histoire, 19, 20 et 21 mai, 1989* (Suze-la-Rousse, 1990), 65–74.

[57] L. Grivetti, 'Wine: The Food with Two Faces', and L. H. Lesko, 'Egyptian Wine Production during the New Kingdom', in McGovern et al. (eds), *The Origins and Ancient History of Wine*, 9–22 and 215–30, respectively (subsequently Lesko, 'Egyptian Wine'). Also see Majno, *Healing Hand*, 186–8, and, most recently, M. E. Weisse et al., 'Wine as a Digestive Aid', *British Medical Journal* 311 (1995), 1657–60. P. Dolara et al. ('Analgesic Effects of Myrrh', *Nature* 379 (1996), 29) report on another potentially valuable medicinal property of myrrh.

[58] *Historia naturalis* 14.57, 92, 107, 112, 131, and 134, with the claim (14.137) that 'there is no department of man's life on which more labour is spent.'

[59] *De re rustica*, 12.19–20.

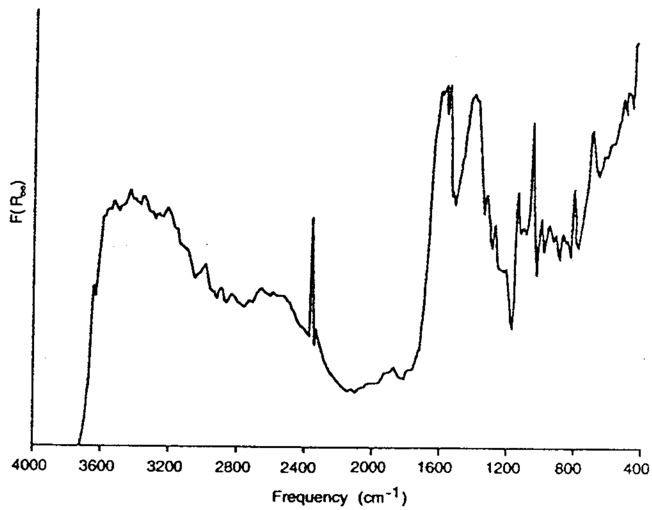


FIG 8. Diffuse-reflectance Fourier transform infrared spectra of a hypothetical mixture of 70% calcium tartrate and 30% pottery fabric (Appendix 1 24).

resins' and 'one of the most persistent drugs in history'.[60] It was already well established as a wine additive in the Neolithic period, and its use continued to expand in later periods throughout the ancient Near East and Egypt.[61] The terebinth tree has been and is widespread and abundant in the Middle East,[62] occurring even in desert areas of Egypt, and a single tree, which can grow to as much as 12 m in height and 2 m in diameter, can yield up to 2 kg of the resin.[63] Its 'turpentine' odour and taste, which was not as concentrated in the resin as in the distillate commonly known by this name today, was evidently not considered to be offensive.[64]

Although local sources might have been exploited in ancient Egypt, terebinth resin was also traded, as demonstrated by the numerous amphoras which were filled a quarter to a half full with resin lumps aboard the Uluburun shipwreck.[65] It should be noted that two of five samples (viz. from amphoras KW 144 and KW 181) from this fourteenth century BC ship also tested positive for tartaric acid/tartrate. Possibly, these jars had once been filled with wine or another grape product, or the terebinth resin might have been used in processing the latter or even preserving fresh or dried fruit.[66]

[60] Majno, *Healing Hand*, 64, 210.

[61] P. E. McGovern et al., 'Neolithic Resinated Wine', *Nature* 381 (1996), 381–1; P. E. McGovern, 'Vin extraordinaire', *The Sciences* 36 (1996), 27–31.

[62] M. Zohary, 'A Monographical Study of the Genus *Pistacia*', *Palestine Journal of Botany, Jerusalem Series* 5 (1952), 187–228.

[63] J. S. Mills and R. White, 'The Identity of the Resins from the Late Bronze Shipwreck at Ulu Burun (Kaş)', *Archaeometry* 31 (1989), 37–44. A. Lucas ('Resin from a Tomb of the Saïte Period', *ASAE* 33 (1933), 187–9; *AEMI*[4], 324) identified 50 kg of a resin inside a sarcophagus as that of *Pistacia atlantica*.

[64] In recent times, it has been used to make chewing gum in Greece (Mills and White, *Archaeometry* 31, 38) and to prepare perfume in the eastern desert of Egypt (M. E. Kislev, 'Reference to the Pistachio Tree in Near East Geographic Names', *PEQ* 117 (1985), 134–8).

[65] Pulak, *AJA* 92, 10–11.

[66] Fruits and other parts of the terebinth tree are most prevalent (Pulak, *AJA* 92, 11). Grape, fig, and olive seeds, as well as pomegranate and terebinth fruit, have also been recovered from the amphoras: see G. F. Bass, 'A Bronze Age Shipwreck at Ulu Burun (Kaş): 1984 Campaign', *AJA* 90 (1986), 278 and *AJA* 93, 10.

Myrrh (Eg. *ʿntyw*), which was indicated for two of the Malkata jars tested, was less widespread and less easily obtained. It was imported from Punt (possibly Somalia) in the New Kingdom, and possibly even successfully transplanted in Thebes.[67]

The tree resin in the Malkata wine is not specifically identified on the wine ostraca, perhaps because a small amount of this material was customarily added to the beverage from an early period. Whether the additive is equivalent to what is called 'resin' (Eg. *sft*; label types 198–9)[68] or 'incense' (Eg. *snṯr*; types 211–14) on other Malkata labels is yet to be verified chemically. It should be pointed out that resins from pine, cedar, and other conifers, which were used in quantity in the mummification process and as aromatics in perfume and incense, had to be imported from abroad, since they grew with more difficulty and in insufficient numbers in Egypt to supply the market. Perhaps sig-

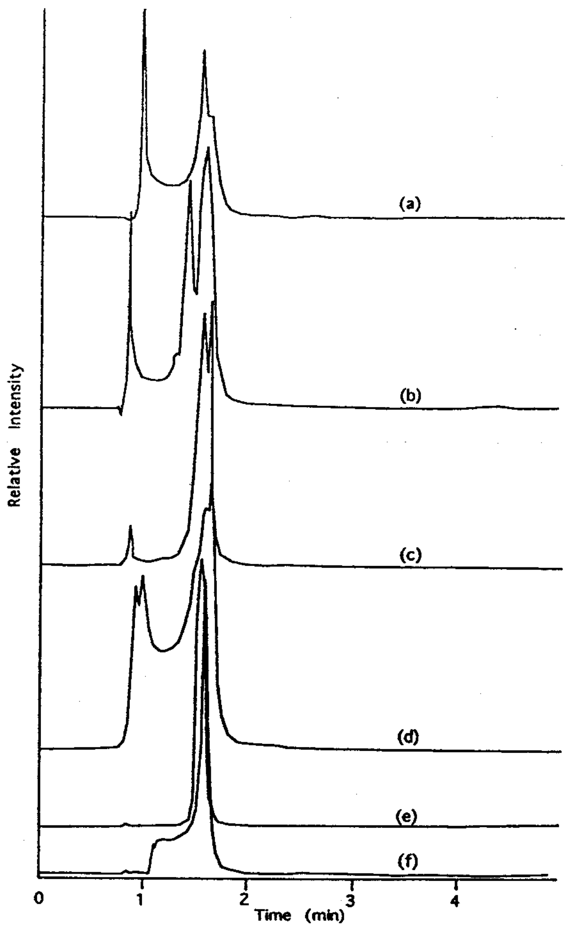


Fig 9. High-performance liquid chromatograms of a. organic sample 5 (Appendix 1 **34**); b. organic sample 6 (**23**); c. red lustrous spindle bottle (Royal Ontario Museum, Egyptian Dept. no. 910.85.15 (B.969)); d. modern myrrh (uncertain origin); e. Chian terebinth resin (sample from amphora KW 144, from the Uluburun shipwreck); f. L-(+) tartaric acid.

[67] *AEMI*, 92–4; Majno, *Healing Hand*, 120–4.
[68] The type numbers are according to Hayes, *JNES* 10.

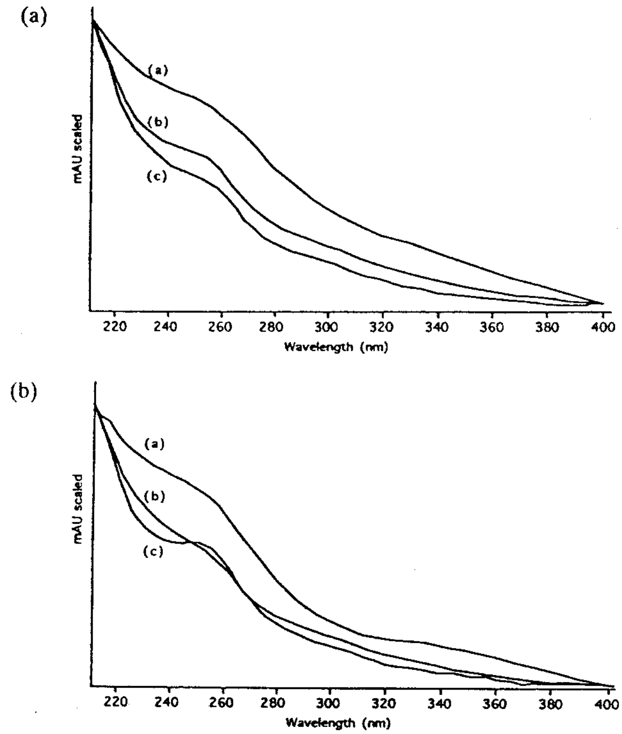


FIG 10. Ultraviolet absorption spectra at retention times of 1.1 (a) and 1.3 min (b) for a. organic sample 5 (Appendix 1 **34**); b. organic sample 6 (**23**); c. L-(+) tartaric acid.

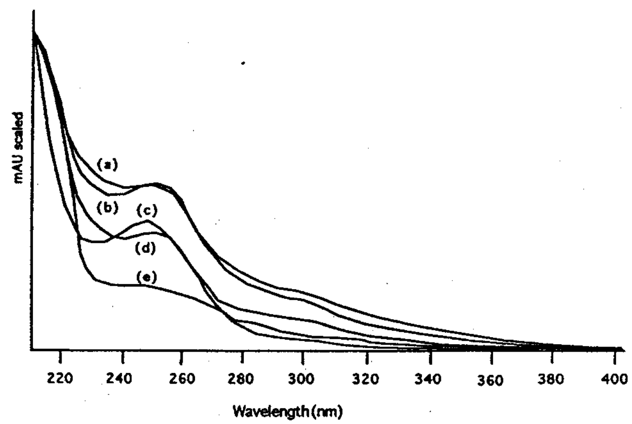


FIG 11. Ultraviolet absorption spectra at retention time of 1.6 min for a. red lustrous spindle bottle (Royal Ontario Museum, Egyptian Dept. no. 910.85.15 (B.969)); b. organic sample 5 (Appendix 1 **34**); c. organic sample 6 (**23**); d. modern myrrh (uncertain origin); e. Chian terebinth resin (sample from amphora KW 144, from the Uluburun shipwreck).

nificantly, four of six Malkata 'incense' jars were contributed to the palace by a captain of a commercial ship in the Mediterranean and Red Sea.[69]

A great deal of supporting documentary evidence exists for the production, transport, storage, and uses of Egyptian wine during the New Kingdom.[70] Tomb paintings vividly illustrate the process of viticulture and viniculture, from the trellised vineyards to the treading of the grapes in circular vats to the bottling and storage of the wine in amphoras (pl. XIV). The careful labelling of wine amphoras is an extension of this Egyptian realism. However, there are some details of the winemaking process that will probably never be known from textual or artistic sources, such as the particular grape varieties which went into these ancient Egyptian wines, whether they were sweet or dry, or whether they could be effectively aged in pottery vessels.[71] Microchemistry may eventually be able to fill in some of these lacunae by analysing for a range of constituents, including sugars, tannins and anthocyanins, and preservatives such as sulphite.[72] Molecular biology may even be able to tell us a great deal more about grape varieties, as well as yeast and bacterial fermentation processes.[73]

The Malkata ostraca are very definite about where most of the wine was produced: the region of the 'Western River', in the north-western Nile Delta, along the Canopic branch of the Nile which enters the Mediterranean at modern Alexandria. El-Amarna itself, the capital of Amenhotep III's son, Akhenaten, yielded 165 ostraca which state that the wine came principally from the 'Western River',[74] and the estates and vineyards listed on the 26 wine amphoras from the Annex of Tutankhamun's tomb[75] are also located there. The relative percentages of wine said to come from other locations than the western Nile Delta—the eastern and central Delta, Memphis, the western oases, and possibly Syria—are quite comparable in the Malkata and Amarna ostraca groups. A century following the Amarna Age,[76] the wine ostraca from the Ramesseum, the mortuary temple of Ramesses II in western Thebes, mention some 30 estates which were situated in a more regular fashion across the whole of the Delta.[77] According to the Great Papyrus Harris (I, 7,

[69] Hayes, *JNES* 10, 94.

[70] Lesko, *King Tut's Wine Cellar* and 'Egyptian Wine'; also see M.-C. Poo, *Wine and Wine Offering in the Religion of Ancient Egypt* (London, 1995).

[71] Lesko, *King Tut's Wine Cellar* and 'Egyptian Wine'.

[72] V. L. Singleton, 'An Enologist's Commentary on Ancient Wines', in McGovern et al. (eds), *The Origins and Ancient History of Wine*, 67–77; McGovern and Michel, 'Two Case Studies'.

[73] P. E. McGovern, 'Introduction: The Making of a Unique Conference, Its Accomplishments, and an Agenda for the Future', in McGovern et al. (eds), *The Origins and Ancient History of Wine*, ix–xv, and 'Science in Archaeology: A Review', *AJA* 95 (1995), 1.

[74] B. Gunn, in T. E. Peet and C. L. Woolley, *The City of Akhenaten*, I (MEES 38; London, 1923), 142–68; H. W. Fairman, in H. Frankfort and J. D. S. Pendlebury, *The City of Akhenaten*, II (MEES 40; London, 1933), 103–9, and III (MEES 44; London, 1951), 143–223. Additional examples are found in M. A. Leahy, 'The Hieratic Labels, 1979–82', in B. J. Kemp (ed.), *Amarna Reports*, II (EES Occasional Publications 2; London, 1985), 65–109.

[75] J. Černý, *Hieratic Inscriptions from the Tomb of Tutankhamūn* (Tutankhamūn's Tomb Series 2; Oxford, 1965), 1–4, 21–4, pls. i–v; also see Holthoer, 'Tutankhamun Pottery', and Hope, 'Tutankhamun Sealings'.

[76] The 'Amarna Age' is sometimes used in a generic sense, especially common in Syro-Palestinian archaeology, to denote the entire fourteenth century BC. In a strict Egyptological sense, the 'Amarna Age' does not begin until the founding of the new capital at el-Amarna by Amenhotep IV/Akhenaten. If one accepts a coregency of Amenhotep III and IV, however, most of the ostraca discussed here do belong to the 'Amarna Age' *in sensu strictu* and are contemporaneous with those found at Amarna (Hayes, *JNES* 10, 36–7).

[77] Lesko, 'Egyptian Wine', 226–7; for Delta vineyards of the Nineteenth Dynasty, see K. A. Kitchen, 'The Vintages of the Ramesseum', in A. B. Lloyd (ed.), *Studies in Pharaonic Religion and Society in Honour of J. Gwyn Griffiths* (EES Occasional Publication 8; London, 1992), 115–23.

10 ff),[78] Ramesses III (*c.* 1184–1153 BC) planted vineyards throughout the Delta, as well as in the oases and to the south of Egypt, using vintners and labourers whom he had captured in foreign expeditions. The king claims (I, 15a, 13 and 18a, 11) to have presented 59,588 jars of wine to his god Amun.

Production of wine in the Delta goes back to a very early period, at least the fourth millennium BC, when cuttings of the domesticated grape vine (*Vitis vinifera*) were probably introduced from Palestine.[79] Wine from this region was already the prerogative of rulers of the Predynastic and Early Dynastic Periods (*c.* 3300–2700 BC), and large jars of the First and Second Dynasties, precursors of the Canaanite jar type, had clay sealing stamped with the names of the kings, possibly the vineyard or estate, and the commodity, wine, in hieroglyphics.[80] Wine was also imported from Palestine.[81] A reassertion of Asiatic influence on winemaking in the Delta, beginning in the early Middle Bronze Age (*c.* 1900 BC), is clear from the excavations at Tell el-Dabʿa, which became the capital (Avaris) of the Semitic rulers called the Hyksos in the seventeenth century BC.[82] NAA and organic analyses also substantiate that wine was being imported in Canaanite jars from the Gaza region of southern Palestine to Tell el-Dabʿa in the north-eastern Delta *c.* 1900–1550 BC.[83] The expansion of the wine industry, the widespread production and use of the Canaanite jar (or amphora) throughout Egypt in the New Kingdom, and the common occurrence of vintners with Semitic names on the Malkata and Amarna Age ostraca (e.g. 'Khoru(y), the Syrian')[84] attest to the long-term impact of the Hyksos on native Egyptian culture.

Egyptian pottery specialists are agreed that the Malkata amphoras are made of Marl D, the most commonly occurring fabric for amphoras in New Kingdom Thebes as well as sites throughout Egypt (e.g. at Amarna, Abydos, Memphis, and Qantir). Because of the mention of the 'Western River' on many of the wine labels and the relative prevalence of Marl D vessel types at Qantir[85] and in the Memphis–Fayyum region,[86] it has been proposed that the source for this clay exists somewhere on the Delta periphery or Middle Egypt,[87] perhaps in the Wadi Natrun, or near Heliopolis, or along the Wadi Tumeilat

[78] J. H. Breasted, *Ancient Records of Egypt* (Chicago, 1906–07), IV, sections 151–412.

[79] T. G. H. James, 'The Earliest History of Wine and Its Importance in Ancient Egypt', in McGovern et al. (eds), *The Origins and Ancient History of Wine*, 197–213 (subsequently James, 'Earliest Wine'); Stager, 'Firstfruits'; P. E. McGovern et al., 'The Beginnings of Winemaking and Viniculture in the Ancient Near East and Egypt', *Expedition* 39 (1997), 3–21.

[80] James, 'Earliest Wine', 198–201.

[81] More than 200 jars of Syro-Palestinian types were found intact and *in situ* in an Early Dynastic royal tomb at Abydos (G. Dreyer, 'Umm el-Qaab: Nachuntersuchungen im frühzeitlichen Königsfriedhof, 5./6. Vorbericht', *MDAIK* 49 (1993), 23–62). NAA and organic analyses by the author and co-workers (see McGovern et al., *Expedition* 39, 5–12) show that wine, with tree resin, grapes and figs as additives, was being imported from the southern Hill Country of Palestine, the Jordan Valley, and Transjordan.

[82] M. Bietak, 'Ein altägyptischer Weingarten in einem Tempelbezirk (Tell el-Dabʿa 1. März bis 10. Juni 1985)', *AÖAW* 122 (1985), 267–78; also see n. 38, above.

[83] McGovern and Harbottle, 'Hyksos' and McGovern, *Foreign Relations*.

[84] Hayes, *JNES* 10, 102.

[85] D. A. Aston, 'Qantir/Piramesse-Nord—Pottery Report 1988', *GM* 113 (1989), 7–24; D. A. and B. G. Aston, 'Pelizaeus-Museum Excavations at Qantir: Pottery Fabrics and Ware Groups', *Ägypten und Levante*, forthcoming.

[86] J. D. Bourriau and P. T. Nicholson, 'Marl Clay Pottery Fabrics of the New Kingdom from Memphis, Saqqara and Amarna', *JEA* 78 (1992), 29–91.

[87] Nordström and Bourriau, 'Ceramic Technology', 181; also see Hope, *Malkata Sealings*, 73–4, and 'Tutʿankhamun Sealings', 99.

where Pliocene and later marl clays are found.[88] Previously, a Theban origin for Marl D was advocated.[89] Known clays in the Nile Delta proper are of alluvial origin, even those of the so-called 'turtle-backs' of Pleistocene date,[90] and are not suitable for making dense, impermeable fabrics, such as are required for shipping liquid goods. The NAA results have helped to resolve the issue of Marl D's clay source, at least in Upper Egypt. The fabric from which the vast majority of the Malkata wine ostraca is made is most likely a local Theban marl clay.

It should be stressed, however, that the exact location of the ancient marl clay deposit that was exploited in the Theban area is unknown. A programme of clay sampling and analyses is needed to resolve this issue, on the assumption that the ancient clay bed was not completely exhausted; if it were, then other deposits in the region may be similar enough chemically to demonstrate a local origin. Marl *tafl* (= shale) deposits, which were laid down between Upper Cretaceous and Miocene times, have been reported at the entrance to the Valley of the Queens and south of Deir el-Moharrib,[91] as well as outcropping in many places along the limestone escarpment.[92] The *tafl* was redeposited secondarily and mixed with Nile alluvium in the early Pleistocene as the Armant formation,[93] which is exposed along the eastern and western cliffs of the Thebaid.[94] These fine-grained calcareous, marly sediments are ideal for pottery-making, as are mixtures of *tafl* and Nile alluvial clay used in modern times to make pottery at a village south of the Birket Habu and in Luxor.[95]

Since Marl B and C fabrics are also included in the local Theban group of Marl D amphoras, it would appear that the macroscopic/sub-microscopic distinctions of the Vienna System of pottery classification are not always correlated with clay origins.[96] The differences between the marl fabrics may also be a function of clay preparation, addition of temper, and firing. Similar New Kingdom industries in the north and south might then have produced Marl D wares that are comparable to one another in inclusional content, colouration, and other physical features, but be made of different clays.[97] At Thebes, Marl D was especially used for amphoras, whereas smaller, more open forms and special artifact types were sometimes made of Marl A4 and Marl B.

The significance of the finding that the Malkata amphoras were probably locally manufactured is that wine and other goods produced in the Nile Delta, Memphis, the

[88] Do. Arnold, 'Ägyptische Mergeltone ("Wüstentone") und die Herkunft einer Mergeltonware des Mittleren Reiches aus der Gegend von Memphis', in Do. Arnold (ed.), *Studien zur altägyptischen Keramik* (Mainz, 1981), 182–3 (subsequently Arnold, 'Mergeltone').

[89] Nordström, *LÄ* VI, 633–4.

[90] For discussion and references, see Arnold, 'Mergeltone', 182, nn. 79–82.

[91] Hope, *Malkata Sealings*, 74, n. 6, and *Three Studies*, 162.

[92] K. W. Butzer, 'Modern Egyptian Clays and Pre-Dynastic Buff Ware', *JNES* 33 (1974), 381–2.

[93] Said, *Geology*, 40–4; also see Tobia and Sayre, 'Analytical Comparison', 110, 112.

[94] R. Said, *The Geological Evolution of the River Nile* (New York, 1981), fig. 12.

[95] Hope, *Three Studies*, 162; P. Brissaud, *Les ateliers de potiers de la région de Louqsor* (BdÉ 78; Cairo, 1982), 69–72; also see Arnold, 'Mergeltone', 177.

[96] Cf. Nordström and Bourriau, 'Ceramic Technology', 175–81.

[97] Before claiming that the Marl D vessels at Qantir and Memphis/Saqqara are of Theban marl clay, chemical analyses of a range of pottery types from these sites need to be carried out. It has been established that Marl D is not a homogeneous group in Lower and Middle Egypt (Bourriau and Nicholson, *JEA* 78, 37–41, 51–4, 71; Nordström and Bourriau, 'Ceramic Technology', 181–2). Perhaps some of the fabric distinctions of the Vienna System have less to do with clay origins than with workshop procedures. Theban pottery practices might well have been transferred to other regions of Egypt.

Fayyum, or possibly Syria, were either 'rebottled' at Thebes for palace use or the vessels were made at Thebes and transported to other regions for filling. Since the Egyptian preposition 'of/from' is non-specific, it is possible to argue that a certain geographic region, estate, or person donated wine which was actually made in Thebes, but this is less likely. Wine production in the hot, dry climate of Thebes,[98] which did become more common in later periods, cannot account for the large amounts of wine that were involved in the *sed*-festivals nor the abundant documentary evidence that Amarna Age wine was produced almost exclusively in the Delta. Rebottling the wine and other commodities in locally made amphoras, which were of uniform type fabric, labelling, and sealing and generally used only once, would be in keeping with the special character of the *sed*-festivities. This scenario assumes a royal pottery-producing centre and central registration facility at Thebes, neither of which has been uncovered in excavations but can be reasonably postulated to have existed.

Potters are known to have been active during the Nineteenth Dynasty at the village of Deir el-Medineh.[99] An antecedent for this industry is attested in the unique pottery workshop scene on a wall painting in the tomb of Kenamun (TT 93),[100] dating to the reign of Amenhotep II and presumably still in operation a half century later at the time of Amenhotep III. Dorothea Arnold[101] suggests that the red-coloured material in two large vats ('baskets') and piled on the ground in the Kenamun tomb scene is a marl clay. The low 'fast' wheel, which is operated with an assistant and combined hand and foot actions of the potter, and multiple examples of pottery types (although not including any amphoras) point to a highly specialised, royal industry.

A royal administrative and registration facility must also have existed to register goods going into and out of the capital and the palace. Scenes in Eighteenth Dynasty Theban tombs clearly show sealings being applied to amphoras and stamped (pl. XIV, 2).[102] A stamp for a fat label, obviously intended for an amphora sealing, was accidentally stamped onto a locally-made mudbrick from Malkata,[103] and a stamp reading 'Wine from the Western River' was recovered from the nearby mortuary temple of Thutmose IV.[104] Therefore, it is conceivable that the postulated royal registration centre would have had a full collection of the necessary stamps for sealing vessels.

The more detailed dockets in ink could also have been added during the registration process, at or about the same time that the Malkata amphoras were sealed in Thebes. This activity is not shown in the tomb paintings, and discrepancies between the stamp and docket inscriptions on the same amphoras in Tutankhamun's tomb[105] are great enough to suggest that the latter were sometimes written at a different time and/or place. The hieratic scripts of the ostraca and sealings, which vary considerably because of the

[98] See Hope, 'Tutankhamun Sealings', 134, n. 118.

[99] Sylvie Marchand, personal communication; also see M. L. Bierbrier, *The Tomb-Builders of the Pharaohs* (London, 1982), 39.

[100] N. de G. Davies, *The Tomb of Ken-Amūn at Thebes* (MMA Egyptian Expedition 5; New York, 1930), p. lix.

[101] 'Techniques and Traditions of Manufacture in the Pottery of Ancient Egypt', in Arnold and Bourriau (eds), *An Introduction to Ancient Egyptian Pottery*, 75–8.

[102] Hope, 'Tutankhamun Sealings', 93–4, 134, n. 118, fig. 2.

[103] Hayes, *JNES* 10, 161.

[104] Hope, 'Tutankhamun Sealings', 97, citing W. M. F. Petrie, *Six Temples at Thebes, 1896* (London, 1897), 7, pl. x.23.

[105] Hope, 'Tutankhamun Sealings', 132.

numerous scribes involved in the labelling process over a protracted period, cannot be localised to any specific region of Egypt.[106]

This scenario of rebottling goods, especially for the *sed*-festival, assumes that the wine and other commodities were delivered to Thebes in other containers. Amphoras with foreign goods, which were probably unlabelled, could have been delivered by ship directly to the registration facility in Thebes (cf. fig. 12). Presumably, amphoras coming from other parts of Egypt would be labelled, and these containers would be disposed of or reused after their contents were transferred. If a pottery vessel lacked a docket or stamped sealing, then bills of lading or inventories, perhaps on papyrus, would have been needed to identify the goods.

While the proposal of a local rebottling and registration process is the most parsimonious explanation for the available evidence, it is possible that the wine amphoras in particular were produced of marl clay in a royal workshop in Thebes, shipped downstream to royal vineyards, primarily in the Delta, filled there, and then returned to Thebes. Wines imported from abroad could also have been transferred to Egyptian Marl D amphoras in the Delta. The main objection to this reconstruction is that none of the Malkata wine sealings is punctured.[107] A young wine shipped up the Nile would have been subject to mixing and heating, and would have produced gases from unfinished or renewed fermentation and other chemical reactions. Puncturing the sealing allows the gases to escape; otherwise, the vessel may explode. To leave the mouth of the amphora open to the air is equally unsatisfactory, since the bacteria that convert wine to vinegar will proliferate. A compromise solution might have been to stuff the mouth of the amphora with reed, leaf and clay bungs and/or pottery sherds, which are found inside most clay sealings, and perhaps to tie a cloth or leather cover over the opening. When the amphora arrived in Thebes, it would then have been permanently sealed, a process which was evidently carried out only once for each vessel.[108] The assumption that an amphora would be sealed as soon as it was filled[109] is thus unlikely for wine, unless the sealing were provided with a secondary fermentation lock, which could be plugged up later. Since none of the Malkata wine vessels was so provided, the most likely explanation is that they were sealed in Thebes.

However, the shipment of empty amphoras, made of Theban marl clay, to the Delta for filling might also help to explain the large numbers of specialised Marl D vessels (flasks, tankards, etc., in addition to amphoras), most likely intended for valuable commodities,[110] which are concentrated in Middle and Lower Egypt in the Eighteenth and Nineteenth Dynasties. A precedent existed for centralised, royal pottery production and distribution. In the Memphite region during the Middle Kingdom and the Second Intermediate Period, specialised Marl C types, especially jars, were concentrated in the area near the capital of Itj-tawy (Lisht) and distributed to a limited extent to other parts of the country.[111] A closely matching Upper Eocene clay source (the Qasr el-Sagha

[106] See Leahy, *Malkata Inscriptions*, 2, 57–63.

[107] Hope, *Malkata Sealings*, 7; cf. 'Tutankhamun Sealings', 135.

[108] Superimposed stamps might conceal evidence of resealing, but, besides being unlikely, there are few such instances: Hope, *Malkata Sealings*, 7–8.

[109] Hope, 'Tutankhamun Sealings', 96, with references.

[110] Hope, *Three Studies*, 14, 99, n. 18.

[111] Arnold, 'Mergeltone', 183–90; Nordström and Bourriau, 'Ceramic Technology', 179–81.

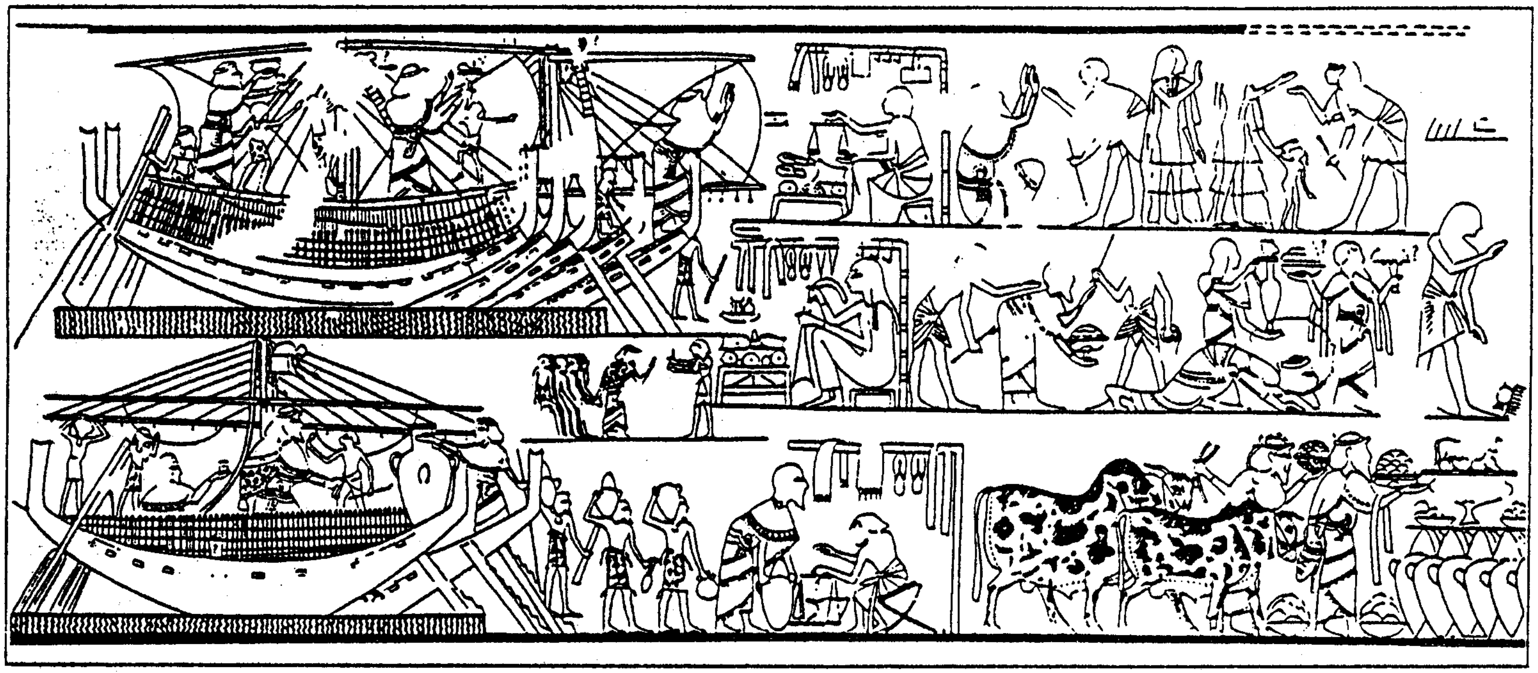


FIG 12. Painting showing amphoras and various goods being unloaded and registered, from the Eighteenth Dynasty tomb of Kenamun (TT 93) (after Davies and Faulkner, *JEA* 33, pl. viii; courtesy of the EES)

formation) for Marl C exists north of Lake Qarun in the Fayyum,[112] not far from Lisht. The contemporaneous Maadi formation shales in the region south of Cairo are of similar chemical composition, as are secondary Pleistocene deposits in the Fayyum basin,[113] and might also have been exploited in antiquity to make Marl C vessels. The well-known modern waterjars made of so-called *kulleh*-clay, a secondarily deposited Pleistocene clay found in the Wadi Qena,[114] represent a recent example of pottery mass-production and distribution.

One of the Malkata wine amphoras was made of Nile alluvial clay, which was also available locally at Thebes. Because of the mixing of sediments along the course of the Nile, the alluvial clays are notoriously inhomogeneous.[115] The particular ostracon (Appendix 1 **34**) is not a tight member of the principal north-eastern Nile Delta clay and pottery group that was used for MED and MDP distance and probability comparisons, suggesting that the sample is from another area along the Nile, possibly Thebes itself.

Among the Malkata wine amphoras that were analysed, only two ostraca (**4** and **16**) were definitely non-local. Both are of a whitish ware, which has been described as similar to the modern *kulleh*-ware made in Qena, about 75 km north of Thebes. These imports, the former stating that it comes from an undefined western oasis and the latter said to be 'of/from *Pr-wsẖ*' (probably the Kharga Oasis), are chemically distinct from one another, and do not match *kulleh*-ware or any other well-defined Egyptian marl clay. The Kharga Oasis is only about 250 km west of Thebes; as the largest and most fertile of the western oases, it was well known for its wine in antiquity.[116] An overland trade route also connected the Kharga Oasis with three other western oases and the Fayyum to the north. Enlargement of the NAA databank for these oases will very likely demonstrate that the two non-local ostraca do originate from where their labels claim they do. The wine in these amphoras was probably not rebottled in vessels made of Theban marl clay, because royal pottery workshops, with access to good marl clays, might well have been established in the major western oases, in particular Kharga, during the Eighteenth Dynasty.

The transport of wine in amphoras of various sizes is clearly attested in New Kingdom paintings.[117] Physical remains of a rope sling for transporting a very heavy amphora were recovered from the Theban tomb of Meryet-Amun,[118] queen of Amenhotep II. Presumably, donkeys were principally used for overland transport from the western oases to Thebes or to reach the nearest point on the Nile where river transport was available. The unloading of amphoras from a Syrian merchantman (fig. 12), possibly even in the harbour of Malkata (Birket Habu), is depicted in the tomb of Kenamun (TT 93), 'Mayor of the Southern City, Overseer of the granary of Amun'.[119]

[112] Said, *Geology*, 102–3; McGovern et al., *BASOR* 296, 40.

[113] Tobia and Sayre, 'Analytical Comparison', 108–12.

[114] Nordström and Bourriau, 'Ceramic Technology', 161.

[115] R. Allen and H. Hamroush, 'The Application of Geochemical Techniques to the Investigation of Two Predynastic Sites in Egypt', in J. B. Lambert (ed.), *Archaeological Chemistry III* (Advances in Chemistry Series 205; Washington, DC, 1984), 51–65.

[116] O. E. Kaper, 'Egyptian Toponyms of Dakhla Oasis', *BIFAO* 92 (1992), 120–1.

[117] E.g. N. de G. Davies, *Paintings from the Tomb of Rekh-Mi-Rēʿ at Thebes* (New York, 1935), pl. 15, showing large and small sealed amphoras being transported into the treasury of Amun at the beginning of the reign of Amenhotep II.

[118] H. E. Winlock, *The Tomb of Queen Meryet-Amūn at Thebes* (MMA Egyptian Expedition 6; New York, 1932), pl. xxxi.

[119] N. de G. Davies and R. O. Faulkner, 'A Syrian Trading Venture to Egypt', *JEA* 33 (1947), 40–6.

The clay origin of the *ben*-oil ostracon (**36**), the only example in the Malkata corpus of an amphora labelled exclusively with this natural product, is very certain. The jar is said to be 'of/from the mayor of She-Sobek', a location usually understood as referring to the Fayyum. The moringa tree (*M. aptera*), from which the oil is derived, is probably indigenous to Egypt and thrives in tropical climates throughout north-eastern Africa and the southern Levant.[120] It is possible that commercial production of the oil in the Amarna Age was carried out at an oasis which is as yet unrepresented in the NAA databank. Moringa nut oil, a sweet, odourless liquid that does not easily become rancid, would be an excellent substitute for tree resin in wine (e.g. the unique ostracon in the Malkata ostracon corpus **32**).

Finally, a few brief remarks about the one Malkata 'ale' jar tested (**37**) are in order. Egypt was primarily a beer-drinking culture, since barley could be grown easily in the alluvial plains in the Nile Valley.[121] Sprouted and dried grain (malt) kept well, until it was ready to be fermented into the beverage. Unlike wine, beer could not be preserved in sealed jars, and had to be drunk soon after it was made. The usual word for 'beer' (Eg. *ḥnqt*) thus occurs only once, if at all,[122] in the Malkata ostracon corpus (**38**). Beer was drunk at feasts and other ceremonies, so it must have generally been supplied to the palace in unlabelled containers. By contrast, what Hayes translates as 'ale' (Eg. *srmt*) is the second most frequently attested commodity in the Malkata amphoras and was evidently imported as a well-preserved solid material from which a liquid beverage was made.[123] The chemical finding of oxalate in the Malkata 'ale' jar indicates that *srmt* was very likely a barley product, as was ordinary beer. The difference between the two commodities might then be that the 'ale' of the Malkata ostraca is a kind of yeast starter which was preserved under relatively acidic and anaerobic conditions[124] and could be transported in sealed amphoras with minimal spoilage. Like yogurt,[125] an acidic milk product fermented using bacteria rather than yeast, it could have been eaten as a solid or diluted with water and drunk. The one definite 'ale' amphora and possibly a second (**38**) were made of probable local Theban marl clay.

The Malkata ostraca have only begun to yield their textual and chemical secrets about court life during one of the most prosperous periods of antiquity. Supplied by goods imported from other parts of Africa and the Eastern Mediterranean, the Malkata palace at Thebes during the reign of Amenhotep III reflects the internationalism of the period, which had profound effects on native Egyptian culture and technology.[126] Fermented beverages had long played an important part in Egyptian economic, social, and religious life. During the Amarna Age and the later New Kingdom, the Egyptian wine industry greatly expanded in the Delta and elsewhere in the country, at the same time that foreign

[120] Stager, 'Firstfruits', 175.

[121] W. Helck, *Das Bier im alten Ägypten* (Berlin, 1971); J. Geller, 'From Prehistory to History: Beer in Egypt', in R. Friedman and B. Adams (eds), *The Followers of Horus: Studies Dedicated to Michael Allen Hoffman, 1944–1990* (Oxford, 1992), 19–26.

[122] According to Hayes' restoration (*JNES* 10, 91).

[123] W. Helck, *Materialen* III, 495–6 (691–2) and IV, 184–5 (792–3); Hayes, *JNES* 10, 91; Leahy, *Malkata Inscriptions*, 5–6, 48, n. 9.

[124] S. H. Katz and M. M. Voigt, 'Bread and Beer: The Early Use of Cereals in the Human Diet', *Expedition* 28 (186), 23–34.

[125] F. W. James, 'Yogurt: Its Life and Culture', *Expedition* 18 (1975) 32–8.

[126] See P. E. McGovern (ed.), *Cross-Craft and Cross-Cultural Interactions in Ceramics* (Ceramics and Civilization 4; Westerville, OH, 1989), 1–11, 147–95.

vintages flowed in from abroad. Several hundred years earlier, the Canaanite jar, the transport container *par excellence*, was probably adopted by Egyptian vintners in the Delta, where it began to be made of locally available Egyptian clays. Its use soon spread to other commodities, so that by the time of the Amarna Age, this amphora type was being produced in large numbers throughout Egypt. At Malkata, foreign and domestic goods of special importance and, to a large extent, fermented beverages or related products, were carefully rebottled in well-made amphoras and flasks of local marl clay, stoppered, sealed, labelled, and presented at special state and religious occasions. The pharaoh and the gods of Egypt, whose purview extended to the limits of then-civilised world, would not have expected anything less.

Appendix 1: Palace of Amenhotep III (Malkata)
Catalogue of ostraca analysed

Wine jars

1 Inscription 10.1:[1] 'Year 30, wine of the estate of Nebmaatre ... Western River ... the chief vintner ... '
Rubbish mounds
Mottled whitish exterior; white residue patches on interior
NAA no. PMG254: probable Theban marl clay

2 Inscription 14.1: 'Wine for the ... first [*sed*-] festival of His Majesty, l.p.h.! (life, prosperity, health!) [of/from] the estate ... '; possibly Year 30
No provenance
White slip on exterior
NAA no. PMG277: probable Theban marl clay

3 Inscription 18.1: '[Year x] + 1, wine of/from [the estate of the Ro]yal Wife, may she live!'
Rubbish mounds
Horizontally defined reddish residue on interior
NAA no. PMG264: probable Theban marl clay

4 Inscription 19.1: 'Year 31, wine of/from the oasis'
No provenance
Whitish fabric
NAA no. PMG331: ?; no matches at MED 0.1—possibly a western oasis marl

5 Inscription 21.1: 'Year 32, wine of/from the [Western] River ... [of/from the estate of ...] ... Splendour-of-the-Aten, the chief [vintner] ... '
Rubbish mounds
NAA no. PMG268: probable Theban marl clay

6 Inscription 23.1: '[Year x] + 2, wine of/from the vineyard [of the mansion of pharaoh, l.p.h.! (life, prosperity, health!)][2]
No provenance
NAA no. PMG269: probable Theban marl clay

7 Inscription 23.2: ' ... vineyard of/from the mansion of pharaoh, l.p.h.! (life, prosperity, health!)';[3] possibly Year 32, based on **8**
No provenance

[1] The type numbers are according to Hayes, *JNES* 10, 35–56, 82–111.
[2] This reconstruction is based on **7**.
[3] The inscription does not mention wine, but the formula supports this interpretation.

NAA no. PMG265: probable Theban marl clay

8 Inscription 24.1 (=MMA 17.10.10): 'Year 32, good wine of/from the mansion'
South Village
Thin, white slip on exterior; red-painted 'potter's mark'
NAA no. PMG259: ?; no matches at MED 0.1—possible Theban marl clay

9 Inscription 33: '[Year] 34, wine of/from the [Western] River ... the [chief] vintner Amenemone'
No provenance
Thick, red residue on interior
Organic sample 9: probable terebinth resin
NAA no. PMG257: probable Theban marl clay

10 Inscription 33.1: '[Year] 34, wine of/from the [Western] River ... the chief vintner Amenemo[ne]'
No provenance
White slip on exterior
NAA no. PMG271: probable Theban marl clay

11 Inscription 41: 'Year 35, wine of/from Per-hebyt (town in central Delta = modern Behbet el-Hajar) ... the chief [vintner] ... '
Middle Palace (Ho.2.W)
Thick, dark brownish residue on interior
Organic sample 7: calcium tartrate and probable terebinth resin
NAA no. PMG263: probable Theban marl clay

12 Inscription 46.1: 'Year 36, wine of/from the Western River'
Middle Palace (Ho.2.B)
NAA no. PMG266: probable Theban marl clay

13 Inscription 48.1: 'Year 36, wine of/from the estate of the overseer of the treasury'
Middle Palace (Ho.2.W)
Thin, reddish residue on interior
NAA no. PMG262: probable Theban marl clay

14 Inscription 48.2 (=MMA 17.10.9): 'Year 36, wine of/from the estate of the overseer of the treasury'
Middle Palace (Ho.2.W)
Whitish exterior
NAA no. PMG260: probable Theban marl clay

15 Inscription 48.3: 'Year 36, wine of/from the estate of the overseer of the treasury'
Middle Palace (Ho.2.W)
Thin, reddish residue on interior
NAA no. PMG261: probable Theban marl clay

16 Inscription 49.1: 'Year 36, good wine of/from *Pr-wsh̲* (literally 'broad house' or 'estate', probably modern Kharga Oasis)'
'Palace', no. 6P1009
Whitish fabric
NAA no. PMG258: ?; no matches at MED 0.1—possibly a western oasis marl

17 Inscription 52.1: 'Year 36, wine of/from Tjaru (=Sile), Panedjebu'; 'very good' written twice, to the right and left, under the handle
Middle Palace (Ho.2.W)
NAA no. PMG273: probable Theban marl clay

18 Inscription 54.1: '[Year 37, w]ine of the estate Nebmaatre l.p.h.! (life, prosperity, health!) [-is-the-Splendour-of-the-Aten of/from the Wes]tern [River], the chief vintner *Nh* ... [Naharin = Mitannian?]'[4]
No provenance
NAA no. PMG248: probable Theban marl clay

19 Inscription 54.2: '... Western River, the chief vintner ... '[5]
Ho.B (labelled B on fig. 1, south of Ho.3.W)
NAA no. PMG276: probable Theban marl clay

20 Inscription 55.1: 'Year 37, wine of/from the Wes[tern] River ... [of/from] the estate of Nebmaatre-l.p.h.! (life, prosperity, health!)-is-the-Splendour-of-the-Aten, chief vintner ... '
Middle Palace (Ho.2.W)
NAA no. PMG270: probable Theban marl clay

21 Inscription 55.2: '[Year 37, win]e of/from the Western River of [the estate Nebmaatre] l.p.h.! (life, prosperity, health!)-is-the-Splendour-of-the-Aten, the chief vintner Ptahmai'
Middle Palace (Ho.2.W)
Yellowish fabric
NAA no. PMG251: probable Theban marl clay

22 Inscription 58.1: 'Year 37, wine of/from the mansion ... [in Men]-nefer (= Memphis), chief vintner'
'Ho.1.B', not shown on fig. 1; excavated by the University of Pennsylvania Museum expedition in the rubbish mounds
NAA no. PMG332: probable Theban marl clay

23 Inscription 59: 'Year [37]'[6]
No provenance
Thick, dark brownish residue on interior
Organic sample 6: tartaric acid and myrrh
NAA no. PMG249: probable Theban marl clay

24 Inscription 60.1: 'Year [37], wine of/from the *ʿ.t-ḥt* (orchard or vineyard?) of Nebmaatre ... 6 *min*'[7]
Palace
NAA no. PMG255: probable Theban marl clay

25 Inscriptions 62.2 + 42.1: 'Year 38, genuine wine' (Inscription 62.2) written over 'Year 36 (37?), wine, season of *prt*, Lifting-up-of-the-year festival, estate [of] Nebmaatre, 9 *min/hin*'[8] (Inscription 42.1)
Middle Palace (Ho.2.W)
Thick, brownish residue on interior
Organic sample 4: calcium tartrate and probable terebinth resin
NAA no. PMG267: probable Theban marl clay

26 Inscription 63: 'Genuine wine';[9] no year
Provenance uncertain

[4] See Hayes, *JNES* 10, 102.

[5] The inscription does not mention wine, but the first line is broken off the sherd, and 'wine' should probably be restored based on other inscriptions of the same type (see Hayes, *JNES* 10, 88–9).

[6] Complete examples include the word 'wine': see Hayes, *JNES* 10, fig. 7.

[7] The volume is *c.* 29–115 l, since *1 min* = *c.* 10–40 *hin*, and 1 *hin* = 0.48 l: see W. Helck 'Masse und Gewichte', *LÄ* III, 1202; J. J. Janssen, *Commodity Prices from the Ramessid Period: An Economic Study of the Village of Necropolis Workmen at Thebes* (Leiden, 1975), 330, 340–1; Hope, *Three Studies*, 109, n. 13.

[8] Viz. *c.* 4.3–173 l; Hayes, *JNES* 10, 105, reads '(of/for) offerings' instead of 'genuine'.

[9] Ibid. 105.

Thick, reddish deposit on interior
Organic sample 2: calcium tartrate and probable terebinth resin
NAA no. PMG228: probable Theban marl clay

27 Inscriptions 63.1 + 54.4: 'Genuine wine' (Inscription 63.1) written over 'Year 37, wine of/from the estate of Amenhotep ... the Western River the chief vintner Pa'[10] (Inscription 54.4)
Middle Palace (Ho.2.W)
NAA no. PMG272: probable Theban marl clay

28 Inscription 73.1: '[Wine] of/from the oasis'; no year
Palace
Hand-burnished white slip on exterior
NAA no. PMG333: probable Theban marl clay

29 Inscription 74.1: 'Very good wine of/from Tjaru (= Sile)'
'Palace', no. 6P1008
Hand-burnished white slip on exterior
NAA no. PMG275: probable Theban marl clay

30 Inscription 74.2: 'Very good wine of/from Tjaru (= Sile)'
Rubbish mounds, no. 6P1008
Hand-burnished white slip on exterior
NAA no. PMG274: probable Theban marl clay

31 Inscription 75.1: 'Wine of/from Tjaru (= Sile), Bay'; no year
Ho.B (labelled B on fig. 1, south of Ho.3.W)
Probable whitish slip on exterior
NAA no. PMG278: probable Theban marl clay

32 Inscription 77.4 + 195bis: '[Wine] of/from Kharu [Syria] ... overseer of the fortress Thutmose' (Inscription 77.4) joins with '... sweet [*b*]*en*-oil of/from ... ' (Inscription 195bis); no year
Palace
Burnished white slip on exterior; reddish deposit on interior
Organic sample 3: calcium tartrate and probable terebinth resin
NAA no. PMG252: probable Theban marl clay

33 Inscription 78: 'Good wine of/from the royal scribe Huy'; no year
Palace
Burnished white slip on exterior; thick, red residue on interior
Organic sample 1: calcium tartrate and probable terebinth resin
NAA no. PMG250: probable Theban marl clay

34 Inscription 81: '[Win]e of/from the *ḫrd n kȝp* ('child of the nursery') *Kmi*'; no year
Rubbish mounds
Shiny black residue on interior
Organic sample 5: tartaric acid and probable myrrh
NAA no. PMG253: Nile alluvial clay

Honey and wine jar

35 Inscriptions 209.1 + 1: 'Honey of/from the beekeeper Huy and the beekeeper Bakamun, [x] *hin*' (Inscription 209.1) written over 'Year 9, wine of the estate Nebmaatre [which is in the] ... the chief vintner Amen[hotep]' (Inscription 1)
Amun temple
Burnished white slip on exterior; red residue on interior

[10] Ibid. 105.

Organic sample 8: calcium tartrate and probable terebinth resin
NAA no. PMG256: probable Theban marl clay

Ben-oil jar

36 Inscription 186.1: 'Fresh *ben*-oil for the *sed*-festival ... [of/from] the mayor of She-Sobek ('the Lake of Sobek' = Fayyum)'; no year
No provenance
NAA no. PMG340: ?; no matches at MED 0.1

'Ale' and possibly 'beer' jars

37 Inscription 103: '*srmt* ('ale'), requirement of/from the mayor of Tjebu'; no year
No provenance
Organic sample 10: oxalate
NAA no. PMG326: probable Theban marl clay

38 Inscription 118.1: ' ... of/from Kedy (= Syria?), of/from the overseer of the fortress (literally, 'sealed place')';[11] no year
No provenance
NAA no. PMG334: probable Theban marl clay

Meat jars

39 Inscription 158.136: 'Year 34, pounded meat ... the stockyard of the chamberlain ... '
No provenance
NAA no. PMG335: probable Theban marl clay

40 Inscription 164.10: 'Year 37, meat ... stockyard of the chamberlain ... '
No provenance
NAA no. PMG336: probable Theban marl clay

41 Inscription 164.11: '[Yea]r 37, pounded meat for the third *sed*-festival ... '
Rubbish mounds
NAA no. PMG337: probable Theban marl clay

42 Inscription 165.3: 'Year 37, pounded meat ... His Majesty l.p.h.! (life, prosperity, health!) of/from the stockyard of the royal [scribe?] ... '
No provenance
NAA no. PMG338: probable Theban marl clay

43 Inscription 166.1: 'Pounded meat ... of/from the *wabet* ('slaughter yard'), Panedjem';[12] no year
Rubbish mounds
NAA no. PMG339: probable Theban marl clay

44 Inscription untyped meat 19: 'Pounded meat for the repetition ... [of the *sed*-festival] ... stockyard of the royal scribe Kha, prepared by the butcher ... '; no year
No provenance
NAA no PMG 341: probable Theban marl clay

45 Inscription untyped meat 21: 'Year 30 + [x], pounded meat'; no year
Probably Amun temple
NAA no. PMG342: probable Theban marl clay

46 Inscription untyped meat 22: 'Year 34, pounded for the repe[tition of the *sed*-festival] ...'
No provenance
NAA no. PMG343: probable Theban marl clay

[11] *hnqt* ('beer') and *srmt* ('ale') have been suggested as restorations by Hayes (*JNES* 10, 91, fig. 9) and C. A. Keller, respectively.
[12] Hayes, *JNES* 10, 92, reads 'as tribute of the heart' instead of 'pounded'.

47 Inscription untyped meat 23: '[Year x] + 1, pounded meat for the ... festival ... '
No provenance
NAA no. PMG344: probable Theban marl clay

48 Inscription untyped meat 24: ' ... prepared by the butcher Mehy';[13] no year
Amun temple, 1915 excavations
NAA no. PMG345: probable Theban marl clay

Appendix 2: Additional Theban ostraca and early Eighteenth Dynasty pottery

Asasif, tomb 703, Twelfth Dynasty
Metropolitan Museum of Art 1934–35 excavations, no. 35.3.290
Tall cylindrical jar (cf. F. W. James and P. E. McGovern, *The Late Bronze Egyptian Garrison at Beth Shan: A Study of Levels VII and VIII* (University Museum Monograph 85; Philadelphia, 1993), 176–8, fig. 97.1—Nineteenth Dynasty), Marl A2
NAA no. PMG455: probable Theban marl clay

Sankhkare Cemetery, pit 1017 (Embalmer's Cache), early Eighteenth Dynasty
Metropolitan Museum of Art 1921–22 excavations, no. 22.2.366
Large ovoid jar, Marl C (sandy)
Hieratic label reads 'natron'
NAA no. PMG447: probable Theban marl clay

Sankhkare Cemetery, pit 1017 (Embalmer's Cache), early Eighteenth Dynasty
Metropolitan Museum of Art 1921–22 excavations, no. 22.3.368
Large ovoid jar with white slip, Marl C (vitrified)
Hieratic label reads 'sawdust of W[am-wood?]'
NAA no. PMG448: probable Theban marl clay

Sheikh Abd el-Qurneh, tomb 252 (Senimen), reign of Hatshepsut, early Eighteenth Dynasty
Metropolitan Museum of Art 1934–35 excavations, no. 35.5.333b
Base of canopic jar, Marl B
NAA no. PMG450: probable Theban marl clay

Valley of the Kings, gift of Theodore M. Davis, late Eighteenth–Nineteenth Dynasty
Metropolitan Museum of Art no. 09.184.775
Ostracon not legible
Amphora, Marl D
NAA no. PMG328: probable Theban marl clay

Valley of the Kings, gift of Theodore M. Davis, late Eighteenth–Nineteenth Dynasty
Metropolitan Museum of Art no. 09.184.781
Ostracon reads ' ... fat ... '
Amphora, Marl D
NAA no. PMG329: probable Theban marl clay

Deir el-Medineh, Nineteenth Dynasty
Excavation no. 6085 C24, inventory no. 354–766
Ostracon reads '[... oil] double good and pure of Egypt, the great land of olive oil [... garden of] Ramesses II in the estate of Amun on the edge of Kamu' (Y. Koenig, *Catalogue des étiquettes de jarres hiératiques de Deir el-Médineh: Nos. 6000–6241* (CG; Cairo, 1979), 16, pl. 9)
Amphora, Marl D
NAA no. PMG327: probable Theban marl clay

[13] The inscription probably refers to meat based on comparable types: see Hayes, *JNES* 10, 91–2, 102.

In Tables 1–5, the compositions of the elemental oxides are cited as weight percentages (pct) or parts per million (ppm).

For Tables 1 and 2, the group (GRP) arithmetic mean composition has been calculated, along with one standard deviation (Std Dev—abs) and the percentage (Std Dev—pct) of the latter from the mean.

TABLE 1. *Neutron Activation Analyses of Malkata Amphoras Made of Probable Theban Marl Clay*

Sample identification	Na_2O[1] (pct)	K_2O (pct)	Rb_2O (ppm)	Cs_2O (ppm)	BaO (ppm)	Sc_2O_3 (ppm)	La_2O_3 (ppm)	CeO_2 (ppm)	Eu_2O_3 (ppm)	Lu_2O_3 (ppm)	HfO_2 (ppm)	ThO_2 (ppm)
PMG228	1.486	1.37	42.8	1.93	266	25.2	40.3	90.0	1.92	0.580	6.92	8.34
PMG248	1.211	1.05	35.7	1.38	208	22.3	38.6	85.3	1.77	0.580	5.98	7.35
PMG249	1.151	1.36	55.5	2.49	405	30.8	40.9	88.7	2.18	0.650	7.05	8.97
PMG250	1.479	0.94	34.8	1.59	328	20.9	35.2	77.6	1.61	0.510	5.96	6.90
PMG251	0.536	1.40	40.5	2.03	348	25.2	42.2	91.6	1.97	0.630	7.33	8.36
PMG252	1.057	1.24	40.2	1.75	399	24.8	41.3	89.3	1.92	0.610	6.90	7.85
PMG254	0.354	1.15	46.5	2.03	380	25.2	41.5	92.9	1.96	0.590	6.04	8.43
PMG255	0.491	1.34	47.0	2.11	352	26.9	43.0	96.2	2.10	0.630	6.49	8.85
PMG256	1.005	1.49	35.2	1.59	341	25.4	37.6	82.4	1.93	0.600	6.35	7.45
PMG257	1.279	1.72	49.0	1.67	397	26.9	38.1	83.8	1.97	0.630	8.20	7.93
PMG260	0.489	1.21	45.5	1.98	351	25.3	43.0	93.3	1.99	0.640	7.02	8.67
PMG261	0.718	0.99	39.1	1.75	283	24.8	37.8	83.8	1.88	0.580	6.89	7.45
PMG262	0.421	1.26	44.0	1.99	276	24.4	40.0	89.3	1.91	0.580	7.16	7.94
PMG263	0.650	1.17	41.8	1.86	358	22.8	38.2	82.6	1.77	0.570	6.12	7.36
PMG264	0.796	1.37	38.5	1.71	384	23.6	38.1	84.1	1.84	0.560	6.65	7.60
PMG265	0.923	1.23	42.8	1.86	336	24.6	40.2	88.5	1.87	0.590	6.34	8.04
PMG266	0.774	1.51	41.5	1.74	424	25.0	38.6	85.7	1.91	0.590	6.92	7.71
PMG267	0.918	1.59	45.3	1.88	476	24.1	38.0	87.3	1.88	0.600	5.81	7.59
PMG268	0.828	1.09	42.2	1.73	206	24.2	37.3	85.7	1.90	0.590	7.40	7.69
PMG269	0.455	1.10	48.0	2.24	350	27.4	43.0	105.0	2.15	0.640	7.38	9.10
PMG270	1.288	1.18	44.8	1.93	248	25.7	39.7	91.0	1.96	0.570	6.15	8.15
PMG271	0.448	1.10	40.6	1.97	373	25.1	41.0	91.4	1.95	0.620	7.23	8.05
PMG272	0.811	1.22	45.0	1.98	430	25.4	41.3	91.0	1.97	0.610	7.36	8.45
PMG273	0.585	1.39	45.7	2.07	308	25.2	41.0	92.5	1.97	0.600	6.65	8.28
PMG274	0.778	1.37	47.9	1.95	256	26.5	41.1	94.6	2.09	0.610	7.40	8.38
PMG275	0.381	1.17	43.4	2.01	313	24.5	40.9	91.0	1.93	0.620	6.73	8.30
PMG276	0.507	1.08	48.3	2.04	259	25.3	41.8	92.9	1.96	0.640	7.30	8.22
PMG277	0.450	1.03	39.5	1.77	246	23.3	37.5	85.5	1.80	0.570	6.52	7.93
PMG278	1.660	1.06	32.7	1.56	330	24.6	39.6	87.7	1.92	0.560	5.94	7.69
PMG326	1.336	1.77	46.1	1.62	429	26.0	31.4	70.8	1.87	0.590	7.26	6.26
PMG332	1.075	1.08	43.9	1.88	304	24.1	38.8	86.7	1.87	0.570	7.55	8.08
PMG333	0.647	1.02	44.5	1.89	208	23.6	39.3	87.0	1.88	0.580	6.90	8.14
PMG334	0.495	1.00	46.1	2.37	374	21.9	45.0	103.2	2.20	0.770	9.01	9.00
PMG335	3.395		41.5	1.86	404	24.0	39.1	86.4	1.87	0.600	6.04	7.77
PMG336	0.938	0.91	39.0	1.92	326	24.0	39.5	88.8	1.92	0.600	5.92	8.30
PMG337	0.525	1.13	42.1	2.06	299	24.0	39.5	88.2	1.84	0.570	6.68	8.43
PMG338	0.992	1.30	46.4	2.09	368	24.9	41.1	92.2	1.97	0.620	6.24	8.47
PMG339	0.762	1.11	42.6	1.85	298	23.0	37.1	83.2	1.84	0.540	6.06	7.58
PMG341	1.398	1.29	34.1	1.72	326	24.5	40.5	91.6	1.95	0.630	6.35	8.50
PMG342	0.819	1.14	37.8	2.02	495	24.5	38.3	86.0	1.86	0.620	6.61	8.26
PMG343	1.298	1.20	39.6	1.88	325	24.6	38.6	86.4	1.94	0.610	5.72	7.94
PMG344	0.554	1.28	42.2	2.08	248	23.9	39.5	90.0	1.86	0.560	6.59	8.55
PMG345	1.628	0.89	37.8	1.71	186	22.1	35.9	79.8	1.70	0.550	7.32	7.41
Number averaged	43	42	43	43	43	43	43	43	43	43	43	43
Arith. mean conc.[2]	0.925	1.22	42.5	1.90	331	24.7	39.5	88.4	1.92	0.599	6.75	8.04
	±	±	±	±	±	±	±	±	±	±	±	±
GRP std dev. (abs)[2]	0.532	0.20	4.6	0.21	72	1.6	2.4	5.9	0.11	0.040	0.67	0.56
GRP std dev. (pct)[2]	57.5%	16.4%	10.7%	11.2%	21.9%	6.6%	6.0%	6.7%	5.9%	6.7%	10.0%	7.0%

TABLE 1. *continued*

Sample identification	Ta_2O_5 (ppm)	Cr_2O_3 (ppm)	MnO (pct)	Fe_2O_3 (pct)	CoO (ppm)	NiO (ppm)	Sb_2O_3 (ppm)	U_3O_8 (ppm)	TiO_2 (pct)	ZrO_2 (ppm)	CaO (pct)	As_2O_3 (ppm)
PMG228	2.01	156	0.120	6.62	24.0	34.3	0.370	3.71	0.891	247	17.6	7.19
PMG248	2.11	145	0.120	5.85	38.1		0.300	3.66	1.033	265	19.2	8.04
PMG249	1.95	211	0.118	7.64	29.7	52.0	2.100	3.26	1.242	258	13.5	3.02
PMG250	1.72	129	0.093	5.62	19.8	46.8	0.380	3.40	0.843	216	21.5	7.46
PMG251	2.09	156	0.109	6.62	23.3	31.6	0.310	4.58	1.026	294	21.0	10.12
PMG252	2.02	152	0.143	6.61	26.4	32.7	0.300	3.45	0.982	279	17.8	9.73
PMG254	2.16	161	0.109	6.75	26.8	54.8	0.460	3.14	0.948	229	21.3	7.82
PMG255	2.15	173	0.111	7.08	25.5		0.400	3.44	0.935	279	21.0	7.62
PMG256	1.91	161	0.123	6.71	24.7	51.4	0.320	3.74	1.064	199	18.9	6.25
PMG257	2.05	175	0.159	7.06	26.1	64.1	0.360	2.77	1.233	310	13.2	4.33
PMG260	2.07	165	0.112	6.70	23.0	38.7	0.330	3.83	1.019	286	15.8	7.11
PMG261	1.95	167	0.132	6.56	24.4	50.1	0.330	3.73	1.109	281	20.1	7.23
PMG262	2.09	175	0.132	6.37	23.2	38.7	0.380	3.75	0.927	285	19.3	8.20
PMG263	1.91	150	0.109	5.89	21.2	50.0	0.350	3.54	0.998	261	19.8	7.24
PMG264	1.94	153	0.117	6.30	22.6	45.1	0.330	3.13	0.897	275	19.6	10.47
PMG265	1.96	164	0.127	6.58	23.4	33.3	0.370	4.59	0.927	272	19.8	9.10
PMG266	1.92	157	0.122	6.49	23.2	45.8	0.370	3.03	1.007	290	19.8	7.57
PMG267	1.94	153	0.142	6.44	24.2	47.9	0.430	4.35	0.865	268	23.4	10.28
PMG268	1.95	161	0.114	6.37	22.2	40.6	0.380	2.84	0.962	297	20.9	9.40
PMG269	2.36	173	0.111	7.28	28.0	79.4	0.320	4.23	1.117	341	19.7	4.91
PMG270	2.10	162	0.119	6.78	24.0	51.5	0.350	4.14	0.991	264	22.8	8.15
PMG271	2.05	157	0.106	6.75	24.5	38.4	0.400	4.08	1.052	261	20.4	8.30
PMG272	2.04	163	0.121	6.68	24.3	37.7	0.430	2.95	0.973	296	20.0	7.40
PMG273	2.13	156	0.115	6.64	24.5	47.5	0.330	4.57	0.964	234	19.8	7.94
PMG274	2.19	167	0.146	7.08	26.5		0.370	4.55	1.062	325	16.2	7.13
PMG275	2.02	154	0.136	6.70	24.4	42.2	0.420	3.92	1.084	278	24.3	8.28
PMG276	2.05	167	0.132	6.89	24.2		0.400	4.00	1.067	343	19.9	5.98
PMG277	1.96	151	0.101	6.27	21.5		0.300	4.26	0.916	278	20.5	4.62
PMG278	1.98	150	0.100	6.52	22.4	54.2	0.410	3.38	0.841	282	17.1	12.30
PMG326	1.48	156	0.131	7.05	28.1	67.5	0.280	2.69	1.228	194	12.0	3.27
PMG332	1.97	154	0.122	6.59	23.4	49.5	0.380	3.74	0.945	311	21.9	7.25
PMG333	1.95	149	0.114	6.69	23.1		0.340	3.44	0.807	272	16.7	7.35
PMG334	1.71	170	0.181	5.81	33.2	55.2	0.560	2.38	0.923	351	17.2	7.79
PMG335	2.01	147	0.144	6.65	23.3	42.4	0.260	4.05	0.547	238	18.8	7.65
PMG336	2.05	154	0.124	6.74	23.5		0.290	3.83	0.951	273	21.1	10.63
PMG337	2.06	157	0.127	6.49	22.7		0.300	3.91	0.895	245	22.1	6.85
PMG338	2.12	161	0.139	7.01	23.8		0.490	4.84	0.840	239	21.2	10.31
PMG339	1.95	151	0.120	6.37	22.3	60.6	0.340	3.28	0.793	221	22.6	7.84
PMG341	2.12	151	0.146	6.63	23.4	50.9	0.300	3.42	0.841	252	21.3	8.32
PMG342	1.99	151	0.134	6.90	24.5	38.2	0.270	3.86	0.850	227	16.8	5.63
PMG343	1.97	158	0.121	6.78	23.6		0.370	3.74	0.787	205	19.9	7.09
PMG344	2.07	151	0.115	6.64	21.6		0.420	3.31	0.791	260	19.1	10.03
PMG345	1.81	144	0.116	6.10	23.0	53.9	0.310	3.97	0.857	291	19.1	9.23
Number averaged	43	43	43	43	43	32	43	43	43	43	43	43
Arith. mean conc	2.00	159	0.124	6.61	24.6	47.7	0.400	3.69	0.954	269	19.4	7.73
	±	±	±	±	±	±	±	±	±	±	±	±
GRP std dev. (abs)	0.14	12	0.016	0.39	3.2	10.7	0.272	0.56	0.132	37	2.6	1.94
GRP std dev. (pct)	7.1%	7.8%	13.3%	5.8%	12.9%	22.3%	68.0%	15.2%	13.8%	13.6%	13.5%	25.1%

TABLE 1. *continued*

Sample identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	Tb_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG228	111	7.73	3.15	0.990	5.83	646
PMG248	88	7.64	3.25	0.960	4.74	764
PMG249	133	7.85	3.31	1.290	6.10	700
PMG250	88	6.76	2.70	0.860	4.11	1531
PMG251	101	8.04	3.25	0.980	5.52	912
PMG252	102	7.94	3.23	1.020	5.24	515
PMG254	97	7.87	3.09	0.990	5.41	682
PMG255	107	8.15	3.28		6.10	975
PMG256	102	7.66	3.27	1.020	5.50	951
PMG257	95	7.80	3.06	0.920	5.08	644
PMG260	94	8.11	3.37	1.060	5.92	659
PMG261	98	7.53	3.05		5.79	1099
PMG262	111	7.80	2.99	0.980	5.57	1112
PMG263	100	7.28	3.01	0.950	5.26	726
PMG264	99	7.40	3.13	0.940	5.30	893
PMG265	109	7.82	3.05	1.010	5.22	1052
PMG266	110	7.64	3.11	0.950	5.53	1143
PMG267	103	7.53	3.15	1.030	4.98	859
PMG268	103	7.36	3.12	0.940	5.12	877
PMG269	110	8.45	3.32	1.180	6.38	757
PMG270	104	7.80	3.24		5.15	679
PMG271	101	7.94	3.16	1.010	5.61	785
PMG272	103	8.09	3.20	1.010	6.43	871
PMG273	102	7.91	2.97		5.11	692
PMG274	104	8.15	3.25	0.990	5.53	632
PMG275	95	7.91	3.29	1.020	5.50	1390
PMG276	111	8.19	3.15	0.940	6.18	796
PMG277	98	7.26	3.01	0.950	5.12	873
PMG278	96	7.69	3.04	0.950	4.84	794
PMG326	122	6.80	2.82	0.790	5.16	479
PMG332	100	7.63	2.81	0.800	5.37	828
PMG333	103	7.72	3.02	0.890	4.82	616
PMG334	91	8.59	3.88	1.090	5.71	303
PMG335	101	7.69	3.23	0.860	3.91	869
PMG336	102	7.81	3.22	0.830	5.59	2217
PMG337	101	7.67	3.14	0.870	5.35	942
PMG338	105	8.09	3.03	0.930	5.57	630
PMG339	100	7.28	2.65	1.190	4.71	1021
PMG341	104	8.05	3.25	0.910	5.36	818
PMG342	97	7.63	3.18	0.850	5.57	822
PMG343	101	7.70	2.82	0.870	4.34	1070
PMG344	98	7.68	2.92	0.870	5.26	750
PMG345	91	7.10	2.66	0.840	4.03	860
Number averaged	43	43	43	39	43	43
Arith. mean conc	102	7.74	3.11	0.962	5.32	866
	±	±	±	±	±	±
GRP std dev. (abs)	8	0.37	0.22	0.105	0.57	307
GRP std dev	8.0%	4.8%	6.9%	10.9%	10.6%	35.5%

TABLE 2. *Neutron Activation Analyses of Additional Theban Ostraca and Early Eighteenth Dynasty Pottery Made of Probable Theban Marl Clay*

Sample identification	Na_2O (pct)	K_2O (pct)	Rb_2O (ppm)	Cs_2O (ppm)	BaO (ppm)	Sc_2O_3 (ppm)	La_2O_3 (ppm)	CeO_2 (ppm)	Eu_2O_3 (ppm)	Lu_2O_3 (ppm)	HfO_2 (ppm)	ThO_2 (ppm)
PMG327	1.01	1.16	38.0	1.72	426	24.3	35.4	77.9	1.85	0.660	6.43	7.20
PMG328	0.69	1.37	52.7	2.78	374	25.7	39.9	84.3	1.91	0.590	6.22	9.02
PMG329	0.71	0.97	37.0	1.63	217	24.3	35.0	77.5	1.78	0.510	5.36	6.85
PMG447	1.28	1.24	38.4	1.83	223	18.3	32.5	71.4	1.59	0.490	7.25	7.05
PMG448	1.51	2.36	49.1	1.66	298	28.3	36.5	82.7	2.06	0.580	8.94	8.06
PMG450	1.09	1.62	46.8	1.70	264	25.5	30.1	66.4	1.80	0.540	5.21	5.86
PMG455	1.34	1.30	39.2	2.08	311	26.3	43.7	94.8	2.17	0.630	5.74	9.63
Number averaged	7	7	7	7	7	7	7	7	7	7	7	7
Arith. mean conc	1.09	1.43	43.0	1.91	302	24.7	36.2	79.3	1.88	0.571	6.45	7.76
	±	±	±	±	±	±	±	±	±	±	±	±
GRP std dev. (abs)	0.31	0.46	6.4	0.41	77	3.1	4.5	9.2	0.19	0.062	1.30	1.31
GRP std dev. (pct)	28.6%	31.9%	14.8%	21.5%	25.5%	12.6%	12.5%	11.6%	10.2%	10.9%	20.1%	17.1%

Sample identification	Ta_2O_5 (ppm)	Cr_2O_3 (ppm)	MnO (pct)	Fe_2O_3 (pct)	CoO (ppm)	NiO (ppm)	Sb_2O_3 (ppm)	U_3O_8 (ppm)	TiO_2 (pct)	ZrO_2 (ppm)	CaO (pct)	As_2O_3 (ppm)
PMG327	1.79	160	0.125	6.45	23.6	40.7	0.350	3.48	0.86	291	19.7	6.55
PMG328	1.71	195	0.090	6.44	22.5	29.7	0.500	3.99	0.91	261	16.4	5.29
PMG329	1.81	167	0.112	6.45	22.3		0.280	3.52	0.98	225	22.2	9.27
PMG447	1.56	119	0.085	5.23	20.0			2.72	0.89	291	10.4	5.27
PMG448	1.72	207	0.116	7.39	29.0	60.6		3.14	1.06	432	9.5	
PMG450	1.46	204	0.114	6.81	26.0	72.2		3.84	1.31	258	21.8	1.98
PMG455	1.54	209	0.086	6.39	26.0	67.4		7.00	1.13	249	14.9	7.33
Number averaged	7	7	7	7	7	5	3	7	7	7	7	6
Arith. mean conc	1.66	180	0.104	6.45	24.2	54.1	0.377	3.96	1.02	287	16.4	5.95
	±	±	±	±	±	±	±	±	±	±	±	±
GRP std dev. (abs)	0.14	33	0.016	0.65	3.0	18.2	0.112	1.41	0.16	68	5.2	2.45
GRP std dev. (pct)	8.2%	18.5%	15.8%	10.0%	12.4%	33.6%	29.8%	35.6%	15.7%	23.8%	31.4%	41.1%

Sample identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	Tb_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG327	95	7.28	3.09	1.030	5.49	1357
PMG328	129	7.35	3.18	1.020	5.23	589
PMG329	96	7.03	2.55	0.950	4.82	953
PMG447	84	6.18	2.68	0.780		376
PMG448	106	7.50	3.20	1.040		575
PMG450	126	6.39	2.68	0.820		943
PMG455	131	8.56	3.25	1.090		615
Number averaged	7	7	7	7	3	7
Arith. mean conc	110	7.18	2.95	0.961	5.18	773
	±	±	±	±	±	±
GRP std dev. (abs)	19	0.78	0.30	0.118	0.34	331
GRP std dev. (pct)	17.5%	10.9%	10.1%	12.3%	6.5%	42.8%

TABLE 3. *Neutron Activation Analysis of Malkata Amphora Made of Nile Alluvial Clay*

Sample identification	Na_2O (pct)	K_2O (pct)	Rb_2O (ppm)	Cs_2O (ppm)	BaO (ppm)	Sc_2O_3 (ppm)	La_2O_3 (ppm)	CeO_2 (ppm)	Eu_2O_3 (ppm)	Lu_2O_3 (ppm)	HfO_2 (ppm)	ThO_2 (ppm)
PMG253	2.30	1.25	49.8	1.29	627	41.2	36.5	81.3	2.63	0.660	7.05	6.34

Sample identification	Ta_2O_5 (ppm)	Cr_2O_3 (ppm)	MnO (pct)	Fe_2O_3 (pct)	CoO (ppm)	NiO (ppm)	Sb_2O_3 (ppm)	U_3O_8 (ppm)	TiO_2 (pct)	ZrO_2 (ppm)	CaO (pct)	As_2O_3 (ppm)
PMG253	2.12	261	0.155	10.8	53.0	75.9	0.340	2.84	2.03	324	3.98	3.78

Sample identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	Tb_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG253	129	8.77	3.67	0.930	6.71	478

TABLE 4. *Neutron Activation Analyses of Malkata Amphoras Possibly from the Western Oases*

Sample identification	Na_2O (pct)	K_2O (pct)	Rb_2O (ppm)	Cs_2O (ppm)	BaO (ppm)	Sc_2O_3 (ppm)	La_2O_3 (ppm)	CeO_2 (ppm)	Eu_2O_3 (ppm)	Lu_2O_3 (ppm)	HfO_2 (ppm)	ThO_2 (ppm)
PMG258	1.31	1.69	23.6	1.86	253	34.7	51.3	106.9	2.57	0.790	5.86	12.3
PMG331	3.40	0.64	24.2	2.02		30.9	38.8	80.0	1.82	0.950	9.94	15.6

Sample identification	Ta_2O_5 (ppm)	Cr_2O_3 (ppm)	MnO (ppm)	Fe_2O_3 (pct)	CoO (ppm)	NiO (ppm)	Sb_2O_3 (ppm)	U_3O_8 (ppm)	TiO_2 (pct)	ZrO_2 (ppm)	CaO (pct)	As_2O_3 (ppm)
PMG258	1.83	161	212	3.33	11.67	29.9	0.530	5.81	1.15	263	18.3	2.70
PMG331	2.40	134	749	2.66	7.46		0.510	6.54	1.26	388	10.5	2.64

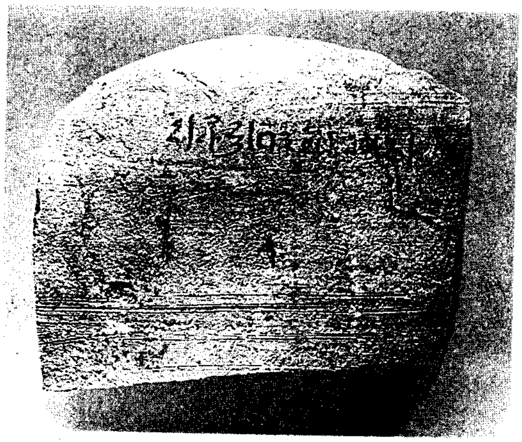
Sample identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	Tb_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG258	133.4	10.26	4.23	1.62	7.48	485
PMG331	55.6	7.88	4.88	1.18	4.74	246

TABLE 5. *Neutron Activation Analyses of Malkata Amphoras of Uncertain Origin*

Sample identification	Na_2O (pct)	K_2O (pct)	Rb_2O (ppm)	Cs_2O (ppm)	BaO (ppm)	Sc_2O_3 (ppm)	La_2O_3 (ppm)	CeO_2 (ppm)	Eu_2O_3 (ppm)	Lu_2O_3 (ppm)	HfO_2 (ppm)	ThO_2 (ppm)
PMG259	1.66	2.16	50.0	2.16	205	27.9	45.5	95.1	2.02	0.590	5.52	10.94
PMG340	1.01	0.58	33.3	1.68	94	17.5	24.4	48.8	1.43	0.350	2.87	4.07

Sample identification	Ta_2O_5 (ppm)	Cr_2O_3 (ppm)	MnO (ppm)	Fe_2O_3 (pct)	CoO (ppm)	NiO (ppm)	Sb_2O_3 (ppm)	U_3O_8 (ppm)	TiO_2 (pct)	ZrO_2 (ppm)	CaO (pct)	As_2O_3 (ppm)
PMG259	1.48	217	582	6.73	19.9	44.9	0.400	4.57	0.957	192	9.7	11.2
PMG340	1.26	179	867	5.71	21.3	42.8	1.110	6.90	0.851	120	25.3	13.7

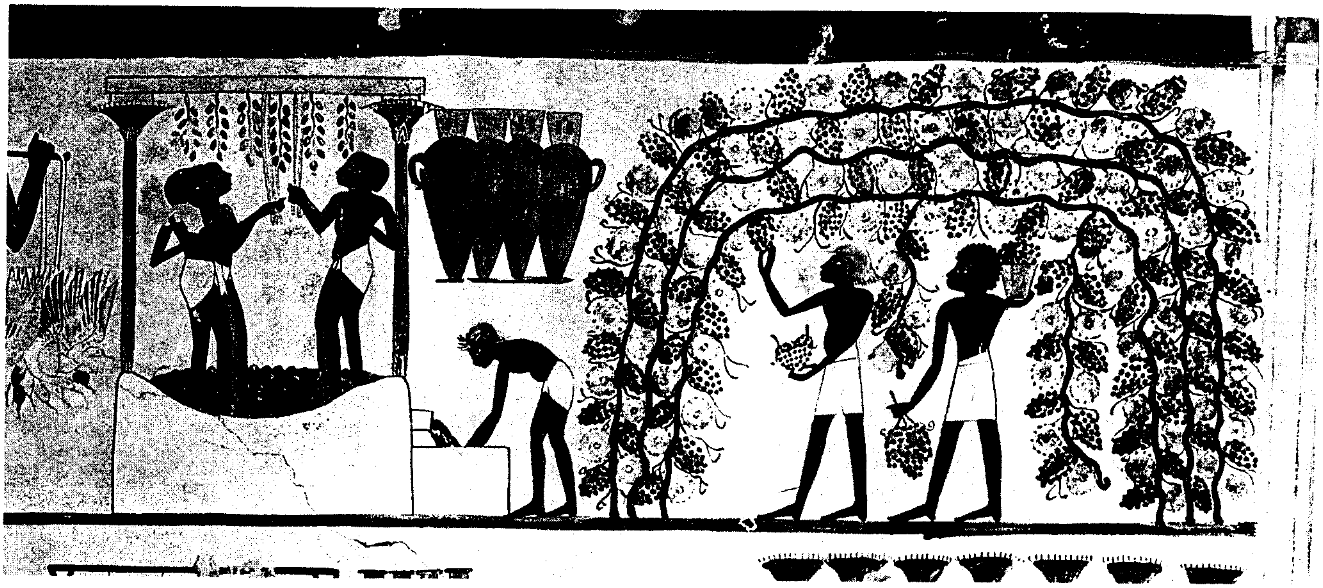
Sample identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	Tb_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG259	155	7.80	2.81	0.940	5.11	678
PMG340	69	5.36	1.86	0.580	3.85	603



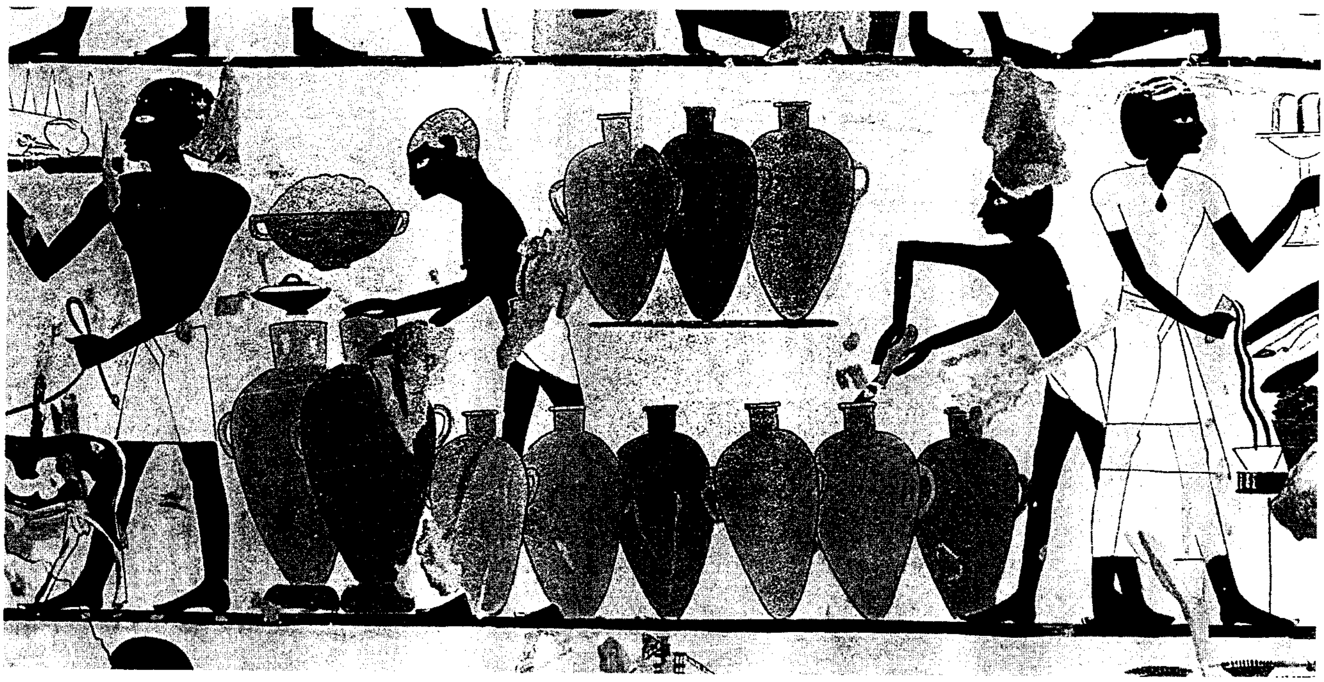
1. Hieratic wine label on a Malkata amphora shoulder fragment (Appendix 1 **13**) (*Courtesy of the Metropolitan Museum of Art, no. 17.10.9*, Rogers Fund, 1917)

2. Upper body of Malkata amphora with hieratic fat label (*Courtesy of the Metropolitan Museum of Art, no. 17.10.2*, Rogers Fund, 1917)

3. Enlargement of 2., reading 'Year 38, the five epagomenal days, the birth of Osiris: fat from the best of the stable, a gift of His Majesty — l.p.h.! (life, prosperity, health!) — [being] an offering of the royal scribe Ahmose, prepared by the controller of fat Yuamun' (Hayes, *JNES* 10, inscription 143, fig. 3; *courtesy of the Metropolitan Museum of Art, no. 17.10.2*, Rogers Fund, 1917)



1. Vintage scene from the tomb of Nakht (TT 52), *c.* 1400 BC (after N. de G. Davies, *The Tomb of Nakht at Thebes* (New York, 1917), pl. 26; *courtesy of the Metropolitan Museum of Art, no. 15.5.19e (facsimile painting)*, Rogers Fund, 1915)



2. Clay sealing being applied to amphora mouth and neck, from the tomb of Khaemweset (TT 261), temp. Thutmosis III — Amenhotep II, fifteenth century BC. (N. M. Davies, *Ancient Egyptian Paintings*, I (Chicago, 1936), pl. xxviii; *courtesy of the Metropolitan Museum of Art, no. 30.4.121 (facsimile painting)*, Rogers Fund, 1930)