UMM EL-QAAB II

Importkeramik aus dem Friedhof U in Abydos (Umm el-Qaab) und die Beziehungen Ägyptens zu Vorderasien im 4. Jahrtausend v. Chr.

VON ULRICH HARTUNG

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2. Materialuntersuchungen an Importgefäßen aus dem Friedhof U in Abydos

THE ORIGINS OF THE TOMB U-j SYRO-PALESTINIAN TYPE JARS AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS

by PATRICK E. MCGOVERN*

Neutron Activation Analysis (NAA), which is an important complement to the organic residue program of the Museum Applied Science Center for Archaeology (MASCA), was carried out to determine the clay source(s) of the jars, on the assumption that the jars were probably manufactured in the vicinity of where the wine was produced.

Eighteen of the Abydos jars (Table 1), representing all the major fabrics in the corpus, were tested. The NAA group constitutes 8.7% of the 207 jars that were recovered from Tomb U-j. Since petrographic analysis had suggested that some of the jars were made of a clay with a granitic and sandstone lithology that is local to Abydos itself[1], samples PMG483–489 were specifically chosen and analyzed to address this issue. One of the small clay sealings (PMG445), which was associated with the wine jars, was also tested.

The main results of the NAA study can be briefly summarized, as follows:

1) Of particular importance is that no identifiable Egyptian clay was used to make the jars.
2) The southern Hill Country of Palestine is attested by three samples (PMG415, PMG485, and PMG487). Two additional samples (PMG488 and PMG489) very likely belong to the same group.
3) The Jordan Valley is attested by three samples (PMG412–PMG414), two of the latter (PMG413 and 414) probably coming from the southern region extending from Kataret es-Samra[c], south of the mouth of the Wadi Zarqa, to Tell Nimrin, at the mouth of the Wadi Shu[c]eib, and the third (PMG412) from the northern region around Tell Abu al-Kharaz, north of the mouth of the Wadi el-Yabis. An additional sample (PMG408) was also likely produced in the southern Jordan Valley.
4) One sample (PMG409) is possibly from Southern Palestine, where a loess clay covers a large area extending from the coast to the inland lowlands and the Negev.
5) The northern Transjordanian plateau is possibly attested by four samples (PMG410, PMG411, PMG417, and PMG484)
6) The central Transjordanian plateau is possibly attested by two samples (PMG416 and PMG418).
7) Southern Transjordan, extending as far south as Petra, is attested by two samples (PMG483 and PMG486).
8) The clay sealing, which was probably used in securing a leather or cloth covering over the mouth of one of the wine jars, was made of Nile alluvial clay. Because of the mixing of sediments along the course of the Nile, a precise region of the river – whether the Delta or Abydos itself – cannot be delimited.

1. Methods and results

The physico-chemical method of NAA has been extensively employed in pottery provenience 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 analyzed. The chemical composition of the 18 pottery samples were determined at the University of Missouri Research Reactor (PMG-series, which denotes the author's first and last names).

Samples were prepared by scraping the surface with a sapphire or silicon carbide 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 aliquots of about 75–100 mg and 200 mg were subjected to short and long irradiations, respectively. The resultant gamma ray data were then processed, incorporating decay corrections, spectrum analyses, and standards, yielding concentrations of 30 elements for each specimen[2]. Following Brookhaven National Laboratory convention, concentrations are reported as oxides of the elements in the order shown in the Tables 2 and 3. Missouri elemental data were converted to the oxides and intercalibrated with the Brookhaven data by multiplying by the relevant factors using a FoxPro database program on an IBM-PC in MASCA.

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[3] in which it is assumed that the chemical variation within a given clay source is less than that between different sources. The inclusions in Egyptian and Levantine pottery, whether deriving from the original clay or added as temper

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[1] N. PORAT and Y. GOREN, personal communications.

[2] The laboratory is under the direction of M. D. GLASCOCK, and receives support from the National Science Foundation (grant no. DBS-9102016). For analytical and statistical procedures, see M. D. GLASCOCK, *Neutron Activation Analysis*, in: H. NEFF (ed.), *Chemical Characterization of Ceramic Pastes in Archaeology*, Madison, WI, 1992, pp. 11–26; H. NEFF, in: *Archaeometry* 36, pp. 115–130.

[3] P. C. WEIGAND/G. HARBOTTLE/E. V. SAYRE, in: T. K. EARLE/J. E. ERICSON (eds.), *Exchange Systems in Prehistory*, New York 1977, pp. 15–34.

TABLE 1 Tomb U-j Analytical Corpus

PMG408: Syro-Palestinian type Storage Jar; U-j 12/15 (cat. no. 104); Ware type I;
NAA Provenience: ?; most similar to PMG476 (Tell Nimrin, southern Jordan Valley)

PMG409: Syro-Palestinian type Storage Jar; U-j 7/17 (cat. no. 298); Ware type III;
NAA Provenience: ?; most similar to JH329 (import from Southern Palestine to Tell el-Dab[c]a, Egypt)

PMG410: Syro-Palestinian type Storage Jar; U-j 10/26 (cat. no. 369); Ware type IV;
NAA Provenience: ?; most similar to PMG351 (collared-rim jar of uncertain provenience from Tell el-Fukhar, northern Transjordanian plateau)

PMG411: Syro-Palestinian type Storage Jar; U-j 12/14 (cat. no. 422); Ware type VI;
NAA Provenience: ?; most similar to PMG379 (Tell el-Fukhar, northern Transjordanian plateau)

PMG412: Syro-Palestinian type Storage Jar; U-j 10/56 (cat. no. 419); Ware type VI;
NAA Provenience: northern Jordan Valley; closest to PMG219 (Chocolate-on-White jar from Beth Shan)

PMG413: Syro-Palestinian type Storage Jar; U-j 10/79 (cat. no. 442); Ware type IX;
NAA Provenience: southern Jordan Valley

PMG414: Syro-Palestinian type Storage Jar; U-j 12/12 (cat. no. 186); Ware type IIa;
NAA Provenience: southern Jordan Valley; closest to PMG093, Chocolate-on-White jar from Kataret es-Samra[c]

PMG415: Syro-Palestinian type Storage Jar; U-j 7/49 (cat. no. 245); Ware type IIb;
NAA Provenience: southern Palestinian Hill Country

PMG416: Syro-Palestinian type Storage Jar; U-j 7/50 (cat. no. 389); Ware type V;
NAA Provenience: ?; most similar to JHSB03 (Sahab, central Transjordanian plateau)

PMG417: Syro-Palestinian type Storage Jar; U-j 10/115 (cat. no. 156); Ware type I;
NAA Provenience: ?; most similar to PMG203 (Tell el-Fukhar, northern Transjordanian plateau)

PMG418: Syro-Palestinian type Storage Jar; U-j 7/14 (cat. no. 434); Ware type VIII;
NAA Provenience: ?; most similar to PMBQ48 (Baq[c]ah Valley, central Transjordanian plateau)

PMG445: Probable clay sealing on Syro-Palestinian type Storage Jar; Tomb U-j, no. 8392
NAA Provenience: Nile alluvial clay

PMG483: Syro-Palestinian type Storage Jar; U-j 10/31 (cat. no. 87); Ware type I;
NAA Provenience: southern Transjordan; closest to Petra local group

PMG484: Syro-Palestinian type Storage Jar; U-j 10/39 (cat. no. 121); Ware type I;
NAA Provenience: ?; most similar to PMG347 (Tell el-Fukhar, northern Transjordanian plateau)

PMG485: Syro-Palestinian type Storage Jar; U-j 10/57 (cat. no. 237); Ware type IIb;
NAA Provenience: ?; most similar to DBHB23 (southern Palestinian Hill Country)

PMG486: Syro-Palestinian type Storage Jar; U-j 10/75 (cat. no. 179); Ware type IIa;
NAA Provenience: southern Transjordan; closest to Petra local group

PMG487: Syro-Palestinian type Storage Jar; U-j, 10/131 (cat. no. 230); Ware type IIb;
NAA Provenience: southern Palestinian Hill Country

PMG488: Syro-Palestinian type Storage Jar; U-j 7/4 (cat. no. 255); Ware type IIb;
NAA Provenience: ?; most similar to DBHB23 (southern Palestinian Hill Country)

PMG489: Syro-Palestinian type Storage Jar; U-j 7/30 (cat. no. 246); Ware type IIb;
NAA Provenience: ?; most similar to DBHB23 (southern Palestinian Hill Country)

by the potter, are generally relatively "pure" (e.g., quartz, calcite, and organic materials) and have a diluent effect on the chemical composition of an ancient sample that is spread across the range of elements.

The author has recently completed a large NAA study of Middle Bronze pottery from the Levant, including 605 pottery and clay samples from the key site of Tell el-Dab[c]a, the ancient "Hyksos" capital of Avaris, in the northeastern Nile Delta[4]. To date, 119 pottery and clay samples have been tested from sites in Middle and Upper Egypt (Fig. 1) – Kahun and Dahshur near Lisht, el-Amarna, Abydos, etc. – that range in date from the Old to the New Kingdom (ca. 2700–1070 B.C.). 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, Tell Aphek, Jaffa, Ashkelon, Tell el-[c]Ajjul, Tell Beit Mirsim, Beth Shan, Pella, Jericho, Tell el-Fukhar, the Baq[c]ah Valley of Transjordan, Jericho and Tell Nimrin, Bab edh-Dhra, etc. –

[4] P. E. MCGOVERN, *The Foreign Relations of the „Hyksos": A Neutron Activation Study of the Middle Bronze Age Pottery from the Eastern Mediterranean, BAR Intern. Ser.* 888, Oxford 2000 (hereafter abbreviated as MCGOVERN, *Hyksos*). For the Levantine and Egyptian local compositional groups, also see P. E MCGOVERN/J. BOURRIAU/ G. HARBOTTLE/S. J. ALLEN, in: *BASOR* 296, 1994, pp. 31–43, and P. E. MCGOVERN, in: *JEA* 83, 1997, pp. 69–108.

TABLE 2 Neutron activation analyses of Tomb U-j jars

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)
PMG4(8	0.411	1.73	60.8	4.77	107.	27.4	43.3	80.7	1.92	0.720	2.74	9.58
PMG409	0.437	0.90	16.1	0.94	757.	11.4	22.8	38.2	1.09	0.450	2.87	3.82
PMG410	0.499	1.78	71.8	5.52	274.	45.1	85.2	175.3	2.75	0.910	9.19	22.82
PMG411	0.365	0.65	24.8	1.93	1667.	18.3	37.3	55.0	1.57	0.730	1.59	5.85
PMG412	0.495	1.15	29.8	1.93	876.	17.5	37.2	54.7	1.53	0.780	1.69	5.85
PMG413	0.345	3.14	55.6	3.08		20.6	20.0	44.6	1.03	0.330	2.83	5.96
PMG414	0.385	3.53	89.6	5.82		35.7	37.7	86.4	2.18	0.760	4.52	9.48
PMG415	1.228	2.31	62.2	4.54	257.	25.5	31.0	68.3	1.61	0.560	7.51	8.03
PMG416	0.520	5.53	94.9	5.92	136.	31.0	30.2	65.9	1.63	0.690	4.27	8.66
PMG417	0.358	1.93	33.7	2.79	629.	30.3	50.4	85.5	1.96	1.060	3.71	9.40
PMG418	0.561	3.53	78.3	4.88	118.	42.1	31.9	72.4	1.74	0.770	5.48	10.25
PMG483	0.391	3.21	101.0	7.00	161.	33.0	35.0	70.0	1.00		4.00	9.00
PMG484	0.667	1.30	36.0	2.00	234.	21.0	37.0	70.0	1.00		4.00	9.00
PMG485	1.329	2.28	63.0	4.00	274.	26.0	26.0	58.0	1.00		6.00	7.00
PMG486	0.284	3.60	105.0	7.00	116.	43.0	32.0	69.0	1.00		4.00	10.00
PMG487	1.393	2.62	65.0	4.00	273.	24.0	26.0	55.0	1.00		5.00	7.00
PMG488	1.461	2.77	64.0	4.00	193.	29.0	24.0	60.0	1.00		5.00	7.00
PMG489	1.638	3.13	79.0	4.00	520.	31.0	28.0	64.0	1.00		5.00	7.00

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)
PMG408	1.12	232.	407.	5.31	16.0	77.5	0.460	10.56	0.700	159.	24.5	9.36
PMG409	0.74	122.	647.	2.73	10.6	70.9	0.600	4.45	0.326	184.	40.2	3.01
PMG410	3.98	303.	329.	9.21	43.6	94.8	0.390	4.91	2.433	425.	2.5	8.83
PMG411	0.68	273.	620.	3.28	13.9	100.9	0.540	10.45	0.289	180.	34.0	3.04
PMG412	0.74	268.	630.	4.53	16.2	67.6	0.660	13.40	0.371	142.	33.0	2.98
PMG413	0.83	108.	402.	4.31	14.0		0.220	2.63	0.580	151.	21.8	7.29
PMG414	1.15	169.	865.	7.28	27.1	83.8	0.490	3.86	0.947	215.	8.7	6.68
PMG415	1.12	128.	543.	5.79	21.0		0.320	4.59	0.896	360.	9.5	5.81
PMG416	1.11	162.	379.	5.90	18.6		0.370	2.38	0.965	201.	9.1	4.96
PMG417	1.38	621.	429.	5.09	14.9	124.4	1.230	22.35	0.918	331.	17.7	26.24
PMG418	1.54	215.	278.	7.73	20.6	64.1	0.540	3.70	1.282	219.	1.7	11.33
PMG483	1.00	194.	470.	6.71	19.0			5.00	0.971	144.	13.7	10.00
PMG484	1.00	392.	880.	4.47	15.0	74.0	1.000	17.00	0.718	352.	21.5	20.00
PMG485	1.00	125.	408.	4.87	19.0			4.00	0.752	304.	10.7	8.00
PMG486	1.00	194.	567.	7.60	26.0	41.0		4.00	1.187	255.	3.0	8.00
PMG487	1.00	119.	452.	4.57	18.0			5.00	0.707	239.	10.5	8.00
PMG488	1.00	139.	401.	5.31	26.0			4.00	0.882	219.	6.6	
PMG489	1.00	148.	711.	5.93	25.0			5.00	0.832	219.	5.6	8.00

Sample Identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	T_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG408	148.	8.10	3.32	1.010	5.23	473.
PMG409	98.	4.48	2.18	0.730	3.46	348.
PMG410	145.	10.49	5.22	1.570	8.00	184.
PMG411	180.	6.47	3.20	0.900	5.02	885.
PMG412	164.	6.50	3.10	0.930	4.79	722.
PMG413	74.	4.20	1.96	0.620	2.68	188.
PMG414	102.	8.40	3.74	1.290	6.65	206.
PMG415		6.89	3.01	0.790	5.30	408.
PMG416	90.	6.62	3.10	0.990	4.77	219.
PMG417	354.	8.72	4.45	1.060	6.02	552.
PMG418	109.	6.83	3.68		5.28	130.
PMG483	105.	7.00	2.00	1.000	5.00	401.
PMG484	249.	7.00	4.00	1.000	5.00	857.
PMG485	75.	6.00	2.00	1.000	3.00	408.
PMG486	101.	7.00	4.00	1.000	6.00	
PMG487	67.	6.00	2.00	1.000	3.00	411.
PMG488	86.	5.00	2.00	1.000	3.00	578.
PMG489	83.	6.00	2.00	1.000	5.00	306.

1 The composition of the elemental oxides are cited as weight percentages (pct) or parts per million (ppm).

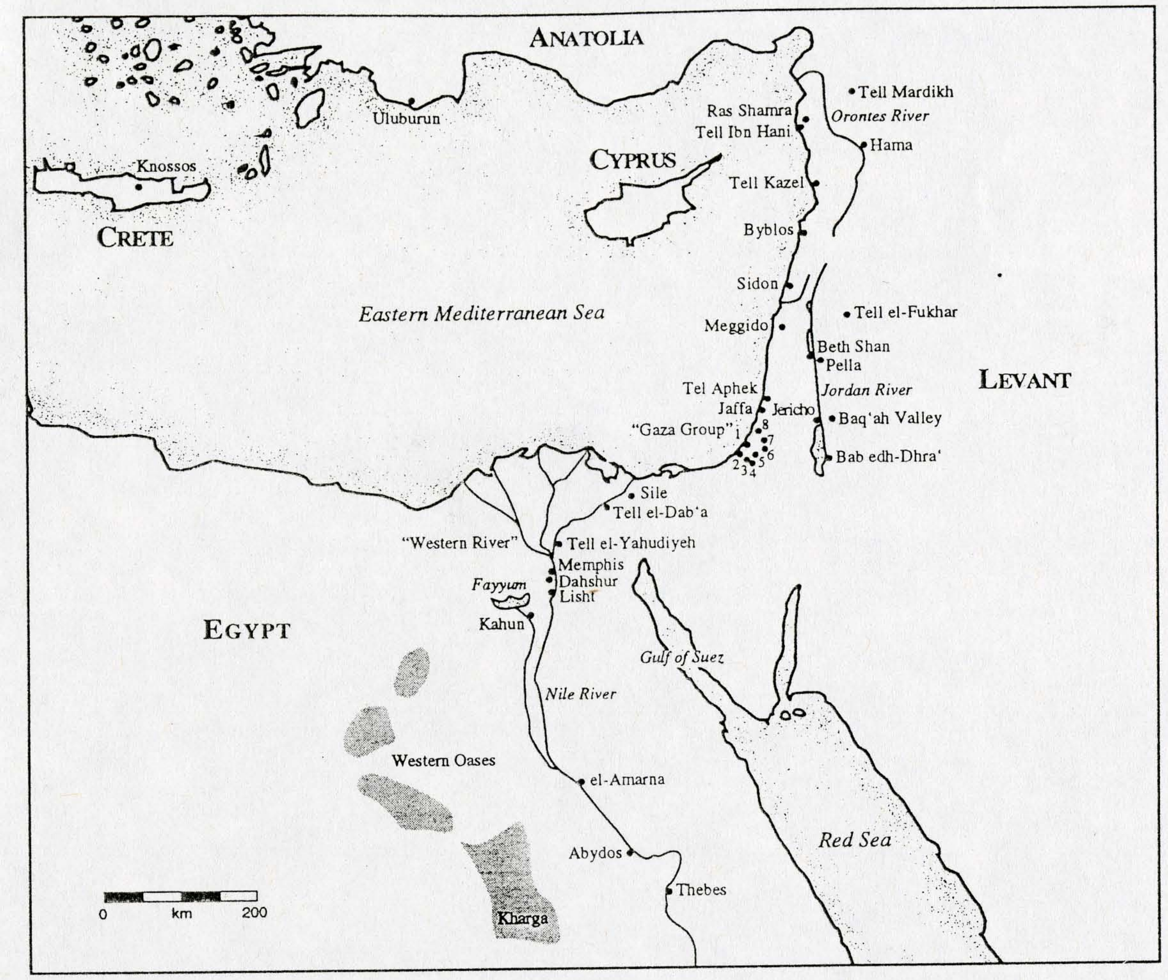

Fig. 1 Eastern Mediterranean region and Egypt, showing some of the sites and regions referred to in the text. The "Gaza group of Middle Bronze Age sites" includes: (1) Gaza; (2) Tell el-ᶜAjjul; (3) Tell Jemmeh; (4) Tell el-Farᶜah South; (5) Tel Haror; (6) Tell Beit Mirsim; (7) Lachish; and (8) Ashkelon.

have also been analyzed. Previous Brookhaven projects[5], accounting for 1208 pottery and clay samples from 79 more Egyptian and Levantine sites, complete the data bank for this region.

The clays that have thus far been analyzed 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 data bank.

The Old World databank on the MASCA computer altogether comprises 6001 samples, most of which were analyzed at Brookhaven. The databank has excellent temporal and spatial coverage of many regions of the Near East and Mediterranean, including Egypt, the Sudan, Greece, Cyprus, Israel and the West Bank, Jordan, Lebanon, Syria, Iraq, Iran, and parts of Turkey. Of most relevance to this study are Levantine and Egyptian pottery and clay groups belonging to the Bronze and Iron Ages.

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 also 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. The geographic extent of a local group is reasonably assumed to have been within a 5–10 km radius of a site during the Bronze and Iron Ages, when clays were probably not transported over longer distances.

The Old World databank was searched for the closest chemical "matches" to the eighteen Abydos wine jars in mean Euclidean distance (MED) space (defined as the square

5 E. g., M. K. Kaplan, *The Origin and Distribution of Tell el Yahudiyeh Ware*, Gothenburg 1980, and D. Brooks/A. M. Bieber, Jr./G. Harbottle/E. V. Sayre, in: C. W. Beck (ed.), *Archaeological Chemistry*, Washington, DC 1974, pp. 48–80 (hereafter abbreviated as Brooks, et al., *Biblical Studies*).

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), cesium (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 variables. An MED of less than 0.08 has been empirically determined to be indicative of group membership and a chemical "match."

The majority of the Abydos jars have MED's that exceed 0.08, generally falling within the range of 0.08–0.10 to the nearest sample in the data base, and consequently have been assigned uncertain proveniences (indicated by a question mark in Table 1). Pending more sampling, the pottery types of the nearest samples and the sites and regions from where they were recovered are potentially important in determining the origin of the Abydos jars. It must also be appreciated that statistically some samples with questionable proveniences are always to be expected, because of natural variability in clay beds, clay preparation by ancient potters, and the analysis itself.

With these provisos, the largest sub-group of Abydos jars with MED's less than 0.08 is that for the southern Palestinian Hill Country. PMG415 and PMG487 are very close to one another, as well as to a group of modern clays that were prepared by potters in Hebron (DBHB02, DBHB03, DBHB05, DBHB11–DBHB13, and DBHB21–DBHB23) from equal parts of Hebron red "field" (loess) clay and yellow marl clay from Arub, north of Hebron, and some added sand from the Gaza region and salt from the Dead Sea[6]. Only somewhat farther afield are PMG485, PMG488, and PMG489.

The southern Jordan Valley sub-group (PMG413 and PMG414; possibly PMG408) is closest to a local pottery group (MED 0.072) from Tell Nimrin[7], at the mouth of the Wadi Shuʿeib in Transjordan, and Chocolate-on-White pottery (MED 0.062) from Kataret es-Samraʿ[8], south of the mouth of the Wadi Zarqa in Transjordan (data as yet unpublished). The latter was found in association with pottery wasters[9], implying local production. Indeed, a Chocolate-on-White waster (PMG084) from Kataret es-Samraʿ, which had been misfired, was chemically closest to a Middle Bronze Age cooking pot (PMG475) of presumed local manufacture at Tell Nimrin.

The single example (PMG412) representing the northern Jordan Valley is closest to a Chocolate-on-White vessel (MED 0.07) from Beth Shan[10] at the juncture of the Jezreel and Jordan Valleys. The latter, in turn, is most similar to probable locally produced Chocolate-on-White pottery, including later debased types, from Tell Abu al-Kharaz[11], north of the mouth of the Wadi el-Yabis in Transjordan and less than 10 km from Beth Shan.

Four Abydos jars (PMG410, PMG411, PMG417, and PMG484) are possibly from the northern Transjordanian plateau, since they are most similar to local samples from Tell el-Fukhar[12] in this region. Yet, the "possible matches" are too distant (MED 0.092–0.117) to be certain, until more analyses of clays and pottery from other sites are carried out.

An origin of two Abydos jars (PMG416 and PMG418) from the central Transjordanian plateau is also suggested by MED's of 0.091 and 0.115 to samples from Sahab[13], south of Amman, and the Baqʿah Valley[14], northwest of Amman, respectively. Again, more sampling and testing are needed to firm up the picture.

Perhaps, the two most intriguing samples in the Abydos NAA corpus are PMG483 and PMG486. The latter match numerous pottery sherds from Petra, which are of local origin[15], in the MED range of 0.07–0.08. Possibly, the Petra clay source extends northwards, where it might have been exploited by a late Chalcolithic/Early Bronze Age people at a site more hospitable to growing grapes and which is, as yet, unrepresented in the NAA database. Alternatively, the climate in the Petra region might have been more temperate at this time, as it was during the Neolithic period at Beidha and Tell Basta.

One sample (PMG409) was very likely exported from Southern Palestine to Abydos. Although the closest sample was at an MED of 0.088, every "possible match" below MED 0.15 – some 50 examples altogether – was from the coastal region of southern Palestine, which extends inland to the lower Shephelah. Most of these matching samples are Canaanite Jars that were imported into Tell el-Dabʿa in the northeastern Nile Delta from the "Gaza group of Middle Bronze Age sites" (Fig. 1), some of which have been chemically determined to contain resinated wine[16].

The numerous MED matches for PMG445, the clay sealing, in the 0.06–0.08 range show unequivocally that it is made of Nile alluvial clay.

[6] Brooks, et al., *Biblical Studies*, pp. 52–55.
[7] J. W. Flanagan/D. W. McCreery, in: *Annual of the Department of Antiquities of Jordan* 34, 1990, pp. 131–152; J. W. Flanagan/D. W. McCreery/K. N. Yassine, in: *Annual of the Department of Antiquities of Jordan* 36, 1992, pp. 89–111.
[8] A. Leonard, Jr., in: *BASOR* 234, 1979, pp. 53–65.
[9] Personal communication, A. Leonard, Jr.
[10] Unpublished, field no. 27.10.447a, Locus 1228, Level IX, University of Pennsylvania Museum no. 29-103-467.
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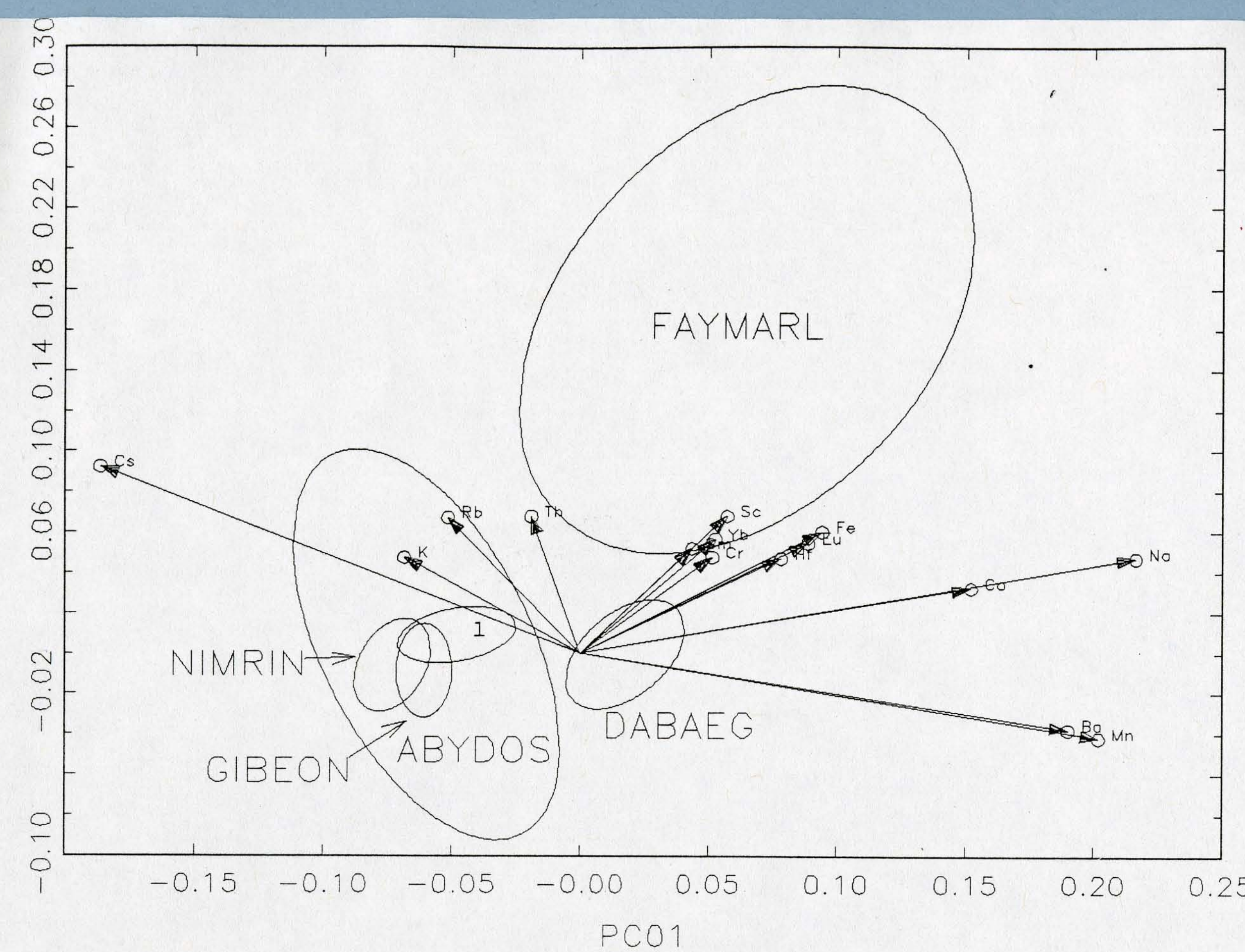

Fig. 2 Plot of variable and object loadings on the first Principal Components (PC01 and PC02) obtained from RQ-mode Principal Component Analysis of the log-normalized data for Egyptian compositional groups, including the Tomb U-j jars analyzed (a smaller group from the southern Palestinian Hill Country is denoted as "1"), a Nile alluvial pottery and clay group at Tell el-Dabʿa (DABAEG), the Upper Eocene Egyptian marl clay that outcrops as the Qasr el-Sagha formation, north of the Fayyum (FAYMARL), a Palestinian Hill Country limestone-derived clay at el-Jib (GIBEON), and a southern Jordan Valley clay (NIMRIN).

It is quite 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. A univariate statistic, like MED, can be very misleading if such relationships go unrecognized.

An especially powerful multivariate statistic, which takes advantage of elemental correlations, is the Mahalanobis probability distance (MDP) of a given sample from the origin or centroid of a defined local group)[17]. Unfortunately, the Abydos sub-groups are too small for this kind of analysis.

Using the set of GAUSS programs that have been developed by H. Neff[18], principal component bivariate plots, based on variance-covariance or correlation matrices and RQ factor analysis, can be conveniently inspected for coherence of groups and any outliers. In Fig. 2, as an example, the 95% confidence ellipses for several local groups, including the main southern Palestinian Hill Country sub-group at Abydos (labeled 1) together with the other wine jars tested (all contained within the larger ABYDOS ellipse), are shown. It is quite apparent that the Nile alluvial clay and pottery group (DABAEG) and the Upper Eocene Egyptian marl clay that outcrops as the Qasr el-Sagha formation, north of Lake Qarun in the Fayyum, and probably extends to the eastern bank of the Nile (FAYMARL) are chemically unlike any of the Abydos samples. The latter are most closely related to Hill Country (e. g., GIBEON/el-Jib), Jordan Valley (e. g., Tell NIMRIN), and Transjordanian local groups[19].

With small groups that are not amenable to MDP evaluation, MED relationships, as well as the determination of outliers, can be graphically represented using a dendrogram generated by a hierarchical aggregative clustering algorithm. In Fig. 3, for example, the close relationship of the five Abydos jars with the modern Hebron loess and marl clays stands out in the top-most cluster. Predictably, many of the samples which possibly come from northern, central, or southern

[17] G. Harbottle, in: E. Pernicka/G. A. Wagner (eds.), *Archaeometry 90*, Basel 1991, pp. 413–424.
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[19] For details, see McGovern, *Hyksos*, pp. 1–30.

TABLE 3 Neutron activation analyses of Tomb U-j jar sealing

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)
PMG445	1.33	1.68	65.2	2.32	558.	32.9	39.2	90.2	2.40	0.750	9.58	8.02

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)
PMG445	2.23	206.	0.154	9.16	38.6	43.6	0.270	4.39	1.68	442.	3.63	3.82

Sample Identification	ZnO (ppm)	Sm_2O_3 (ppm)	Yb_2O_3 (ppm)	T_2O_3 (ppm)	Dy_2O_3 (ppm)	SrO (ppm)
PMG445	130.	8.33	3.51	0.550	5.45	309.

[1] The composition of the elemental oxides are cited as weight percentages (pct) or parts per million (ppm).

```
         48  PMG485-.
3.32E-2  50  PMG487-'---.
6.82E-2  51      PMG488-'-.
1.01E-1  42        PMG415-'---.
1.30E-1  52            PMG489-I
1.34E-1  53            HEBRON-'-----.
1.97E-1  16        GIBEON-.         I-.
9.00E-2  18       JERICHO-'---.     I I
1.29E-1  20           SAHAB-. I-.   I I
1.18E-1  21          BAQ`AH-'-' I   I I
1.60E-1  40              PMG413-'---' I
2.10E-1  19             DEADSEA-.     I-.
1.50E-1  23              BETHSH-'-----' I
2.26E-1   7              AMARNA-.       I-.
1.58E-1  47              PMG484-'-----. I I
2.08E-1  26                    BYBLOS-'-' I
2.55E-1  43          PMG416-.             I---.
1.02E-1  45          PMG418-'-.           I   I
1.41E-1  46          PMG483-. I---.       I   I
1.12E-1  49          PMG486-'-I   I       I   I
1.37E-1  41            PMG414-'   I       I   I
1.68E-1  35                PMG408-'-----. I   I
2.26E-1  17                      HILLCL-'-'   I
2.85E-1   5           FAYMARL-.               I-.
1.40E-1   6             KAHUN-'-----------.   I I
2.46E-1  37                        PMG410-'---' I
3.07E-1   9       `AJJUL-.                      I-.
6.29E-2  11       FAR`AH-'-.                    I I
9.05E-2  10       ASHKEL-. I-.                  I I
7.26E-2  14       GAZACL-'-' I                  I I
1.07E-1  15            APHEK-I                  I I
1.12E-1  12          LACHISH-I                  I I
1.19E-1   1      DABAPAL-.   I-----.            I I
6.97E-2  34       IFSHAR-'---'     I            I I
1.78E-1   2         DABAEG-.       I---------.  I I
8.35E-2   4        FAQUSCL-I       I         I  I I
8.99E-2   3         DABACL-'---.   I         I  I I
1.40E-1  33             MTOUNE-'---'         I  I I
2.72E-1  13          BEITMIR-.              I---' I
1.13E-1  22           FUKHAR-'---.           I    I
1.45E-1  32                 EBLA-'---.       I    I
1.83E-1  24              MEGIDDO-.   I---.   I    I
1.46E-1  25                SIDON-'---'   I   I    I
2.33E-1  38           PMG411-.           I-. I    I
1.16E-1  39           PMG412-'---------. I I I    I
2.04E-1  36                     PMG409-'-' I I    I
2.57E-1  44                         PMG417-'-'    I
3.24E-1  30                             IBNHANI-. I-.
3.08E-1  31                             ORONTES-'-' I
3.54E-1  27                    `ARQA-.              I-------------------.
1.95E-1  28                    KAZEL-'--------------'
```

Fig. 3 Dendrogram of analyzed Tomb U-j Syro-Palestinian type jars, and major Levantine and Egyptian local compositional groups.

E-1 and E-2 indicate that the entry should be multiplied by 0.1 or 0.01, respectively. The first left-hand column gives the mean Euclidean distance to a node on the dendrogram, which is displaced horizontally in direct proportion to the mean Euclidean distance. The second left-hand column gives the order of hierarchical cluster formation, which is not always the same as a nearest neighbor ordering in mean Euclidean space (see Table 4 and text). For abbreviated group names, see text and Fig. 1.

PMG408	PMG418	1.52E-1	SAHAB	1.60E-1	PMG483	1.62E-1	PMG416	1.69E-1	PMG414	1.74E-1	PMG413	1.79E-1	PMG486	1.81E-1
	JERICHO	2.07E-1	PMG484	2.18E-1	PMG415	2.22E-1	BAQ`AH	2.22E-1	AMARNA	2.24E-1	PMG488	2.28E-1	GIBEON	2.30E-1
	HILLCL	2.32E-1	PMG485	2.38E-1	BYBLOS	2.38E-1	PMG487	2.39E-1	PMG417	2.59E-1	PMG410,	2.65E-1	BETHSH	2.78E-1
	HEBRON	2.84E-1	KAHUN	2.86E-1	PMG489	3.01E-1	PMG412	3.05E-1	`ARQA	3.14E-1	FAYMARL	3.15E-1	DABAPAL	3.15E-1
	GAZACL	3.21E-1	DEADSEA	3.26E-1	EBLA	3.27E-1	ASHKEL	3.28E-1	LACHISH	3.42E-1	BEITMIR	3.46E-1	MTOUNE	3.47E-1
	IFSHAR	3.47E-1	IBNHANI	3.54E-1	DABACL	3.68E-1	FUKHAR	3.70E-1	FAQUSCL	3.73E-1	ORONTES	3.74E-1	FAR`AH	3.75E-1
	`AJJUL	3.84E-1	PMG411	3.91E-1	DABAEG	3.97E-1	APHEK	4.00E-1	KAZEL	4.02E-1	PMG409	4.02E-1	MEGIDDO	4.56E-1
	SIDON	4.73E-1	RASSHAM	5.80E-1	THEBES	1.08E+0								
PMG409	PMG412	1.99E-1	BETHSH	2.05E-1	PMG411	2.10E-1	IFSHAR	2.40E-1	EBLA	2.41E-1	DEADSEA	2.45E-1	DABAPAL	2.46E-1
	MEGIDDO	2.55E-1	BEITMIR	2.74E-1	FUKHAR	2.86E-1	PMG413	2.86E-1	PMG484	2.92E-1	SIDON	2.99E-1	AMARNA	3.01E-1
	ASHKEL	3.12E-1	JERICHO	3.13E-1	LACHISH	3.14E-1	GIBEON	3.16E-1	`AJJUL	3.19E-1	BYBLOS	3.21E-1	FAR`AH	3.27E-1
	PMG417	3.36E-1	APHEK	3.50E-1	BAQ`AH	3.57E-1	PMG487	3.58E-1	PMG485	3.59E-1	GAZACL	3.61E-1	HEBRON	3.61E-1
	SAHAB	3.66E-1	MTOUNE	3.78E-1	DABAEG	3.78E-1	PMG415	3.83E-1	PMG489	3.87E-1	PMG488	3.96E-1	KAHUN	3.98E-1
	PMG408	4.02E-1	FAQUSCL	4.17E-1	DABACL	4.18E-1	PMG414	4.39E-1	PMG483	4.48E-1	FAYMARL	4.52E-1	HILLCL	4.62E-1
	PMG416	4.67E-1	RASSHAM	4.68E-1	PMG418	4.75E-1	KAZEL	4.91E-1	IBNHANI	4.92E-1	PMG486	4.98E-1	ORONTES	5.02E-1
	PMG410	5.16E-1	`ARQA	5.25E-1	THEBES	1.01E+0								
PMG410	`ARQA	1.98E-1	PMG418	2.08E-1	SAHAB	2.20E-1	BAQ`AH	2.25E-1	PMG414	2.30E-1	KAHUN	2.44E-1	ORONTES	2.48E-1
	FAYMARL	2.49E-1	PMG415	2.53E-1	PMG486	2.60E-1	PMG408	2.65E-1	BYBLOS	2.69E-1	PMG416	2.70E-1	PMG483	2.74E-1
	GAZACL	2.76E-1	PMG417	2.80E-1	JERICHO	2.87E-1	GIBEON	2.90E-1	MTOUNE	2.94E-1	PMG488	3.01E-1	AMARNA	3.02E-1
	IBNHANI	3.05E-1	PMG485	3.05E-1	ASHKEL	3.07E-1	KAZEL	3.17E-1	PMG484	3.21E-1	HEBRON	3.21E-1	PMG487	3.22E-1
	DABACL	3.22E-1	PMG489	3.22E-1	DABAPAL	3.26E-1	FAR`AH	3.27E-1	LACHISH	3.31E-1	FAQUSCL	3.34E-1	BEITMIR	3.39E-1
	`AJJUL	3.39E-1	APHEK	3.44E-1	FUKHAR	3.44E-1	DABAEG	3.53E-1	EBLA	3.55E-1	IFSHAR	3.58E-1	PMG413	3.73E-1
	HILLCL	3.73E-1	DEADSEA	3.78E-1	PMG412	3.95E-1	BETHSH	3.99E-1	SIDON	4.50E-1	MEGIDDO	4.50E-1	PMG411	4.60E-1
	PMG409	5.16E-1	RASSHAM	6.14E-1	THEBES	1.15E+0								
PMG411	PMG412	1.16E-1	EBLA	1.89E-1	PMG409	2.10E-1	MEGIDDO	2.19E-1	FUKHAR	2.22E-1	SIDON	2.25E-1	PMG417	2.52E-1
	BEITMIR	2.64E-1	DABAPAL	2.75E-1	IFSHAR	2.75E-1	PMG413	2.75E-1	PMG484	2.96E-1	AMARNA	3.08E-1	BETHSH	3.13E-1
	DEADSEA	3.14E-1	BYBLOS	3.23E-1	`AJJUL	3.25E-1	BAQ`AH	3.33E-1	ASHKEL	3.40E-1	FAR`AH	3.43E-1	SAHAB	3.44E-1
	GIBEON	3.45E-1	JERICHO	3.54E-1	MTOUNE	3.57E-1	RASSHAM	3.58E-1	PMG414	3.62E-1	APHEK	3.66E-1	GAZACL	3.69E-1
	LACHISH	3.73E-1	DABAEG	3.79E-1	PMG489	3.86E-1	PMG487	3.89E-1	PMG485	3.90E-1	PMG408	3.91E-1	HEBRON	3.96E-1
	PMG415	4.00E-1	KAHUN	4.07E-1	FAQUSCL	4.11E-1	DABACL	4.18E-1	IBNHANI	4.23E-1	PMG488	4.24E-1	ORONTES	4.35E-1
	PMG483	4.38E-1	KAZEL	4.40E-1	FAYMARL	4.41E-1	`ARQA	4.56E-1	PMG410	4.60E-1	PMG416	4.70E-1	PMG418	4.70E-1
	HILLCL	4.72E-1	PMG486	4.81E-1	THEBES	1.04E+0								
PMG412	PMG411	1.16E-1	EBLA	1.41E-1	FUKHAR	1.88E-1	PMG417	1.96E-1	PMG409	1.99E-1	BEITMIR	2.10E-1	DABAPAL	2.11E-1
	AMARNA	2.11E-1	PMG484	2.13E-1	MEGIDDO	2.18E-1	PMG413	2.24E-1	IFSHAR	2.26E-1	BETHSH	2.41E-1	DEADSEA	2.44E-1
	JERICHO	2.62E-1	SIDON	2.64E-1	SAHAB	2.66E-1	BAQ`AH	2.66E-1	GIBEON	2.69E-1	BYBLOS	2.70E-1	ASHKEL	2.71E-1
	`AJJUL	2.74E-1	MTOUNE	2.85E-1	FAR`AH	2.87E-1	GAZACL	2.99E-1	PMG487	3.01E-1	PMG489	3.01E-1	PMG485	3.04E-1
	PMG414	3.05E-1	PMG408	3.05E-1	LACHISH	3.07E-1	DABAEG	3.11E-1	PMG415	3.13E-1	APHEK	3.16E-1	HEBRON	3.18E-1
	PMG488	3.30E-1	KAHUN	3.34E-1	FAQUSCL	3.35E-1	DABACL	3.38E-1	IBNHANI	3.50E-1	PMG483	3.52E-1	PMG416	3.76E-1
	FAYMARL	3.78E-1	PMG418	3.79E-1	RASSHAM	3.85E-1	ORONTES	3.85E-1	PMG410	3.95E-1	PMG486	3.96E-1	KAZEL	3.97E-1
	HILLCL	4.04E-1	`ARQA	4.05E-1	THEBES	1.05E+0								
PMG413	GIBEON	1.31E-1	JERICHO	1.54E-1	BETHSH	1.59E-1	BAQ`AH	1.76E-1	SAHAB	1.79E-1	PMG408	1.79E-1	PMG483	1.79E-1
	PMG416	1.88E-1	PMG487	1.92E-1	BEITMIR	1.99E-1	PMG485	2.01E-1	EBLA	2.06E-1	HILLCL	2.07E-1	PMG488	2.14E-1
	DEADSEA	2.22E-1	PMG412	2.24E-1	PMG418	2.28E-1	PMG415	2.32E-1	PMG486	2.33E-1	PMG414	2.37E-1	PMG489	2.41E-1
	MEGIDDO	2.44E-1	AMARNA	2.45E-1	HEBRON	2.47E-1	IFSHAR	2.52E-1	DABAPAL	2.53E-1	PMG484	2.60E-1	FUKHAR	2.62E-1
	SIDON	2.64E-1	BYBLOS	2.68E-1	PMG417	2.72E-1	PMG411	2.75E-1	PMG409	2.86E-1	ASHKEL	2.92E-1	LACHISH	3.01E-1
	`AJJUL	3.03E-1	ORONTES	3.10E-1	MTOUNE	3.15E-1	GAZACL	3.27E-1	FAR`AH	3.33E-1	KAHUN	3.33E-1	APHEK	3.51E-1
	DABAEG	3.71E-1	PMG410	3.73E-1	FAYMARL	3.75E-1	DABACL	3.80E-1	FAQUSCL	3.80E-1	IBNHANI	3.82E-1	`ARQA	4.00E-1
	KAZEL	4.61E-1	RASSHAM	5.45E-1	THEBES	1.09E+0								
PMG414	PMG486	1.21E-1	BAQ`AH	1.31E-1	PMG416	1.38E-1	PMG483	1.53E-1	SAHAB	1.57E-1	PMG418	1.59E-1	PMG408	1.74E-1
	GIBEON	1.81E-1	ORONTES	1.88E-1	JERICHO	1.95E-1	PMG415	1.97E-1	MTOUNE	2.08E-1	`ARQA	2.09E-1	BEITMIR	2.12E-1
	PMG489	2.25E-1	HILLCL	2.27E-1	PMG410	2.30E-1	FUKHAR	2.32E-1	PMG413	2.37E-1	PMG488	2.40E-1	IBNHANI	2.43E-1
	EBLA	2.45E-1	PMG487	2.46E-1	PMG485	2.47E-1	BYBLOS	2.54E-1	AMARNA	2.55E-1	GAZACL	2.56E-1	PMG417	2.60E-1
	ASHKEL	2.61E-1	DABAPAL	2.65E-1	HEBRON	2.69E-1	`AJJUL	2.70E-1	IFSHAR	2.79E-1	FAQUSCL	2.80E-1	PMG484	2.82E-1
	KAHUN	2.90E-1	FAR`AH	2.92E-1	APHEK	2.95E-1	MEGIDDO	2.96E-1	LACHISH	2.97E-1	PMG412	3.05E-1	DABACL	3.06E-1
	SIDON	3.06E-1	DABAEG	3.08E-1	DEADSEA	3.12E-1	KAZEL	3.16E-1	BETHSH	3.32E-1	FAYMARL	3.44E-1	PMG411	3.62E-1
	PMG409	4.39E-1	RASSHAM	5.58E-1	THEBES	1.15E+0								
PMG415	PMG485	9.10E-2	PMG487	1.01E-1	PMG488	1.11E-1	JERICHO	1.28E-1	HEBRON	1.33E-1	KAHUN	1.38E-1	PMG489	1.42E-1
	AMARNA	1.69E-1	GIBEON	1.70E-1	SAHAB	1.81E-1	GAZACL	1.82E-1	BAQ`AH	1.83E-1	PMG416	1.91E-1	PMG418	1.91E-1
	PMG414	1.97E-1	ASHKEL	2.00E-1	LACHISH	2.00E-1	DEADSEA	2.01E-1	PMG483	2.06E-1	DABAPAL	2.12E-1	FAYMARL	2.13E-1
	PMG408	2.22E-1	BYBLOS	2.29E-1	DABACL	2.32E-1	BEITMIR	2.32E-1	PMG413	2.32E-1	FAR`AH	2.35E-1	PMG484	2.35E-1
	BETHSH	2.37E-1	MTOUNE	2.41E-1	`AJJUL	2.44E-1	PMG410	2.53E-1	PMG486	2.53E-1	FAQUSCL	2.55E-1	IFSHAR	2.59E-1
	DABAEG	2.60E-1	IBNHANI	2.67E-1	APHEK	2.80E-1	ORONTES	2.89E-1	PMG417	2.94E-1	FUKHAR	3.00E-1	EBLA	3.03E-1
	PMG412	3.13E-1	`ARQA	3.23E-1	HILLCL	3.45E-1	MEGIDDO	3.71E-1	KAZEL	3.81E-1	PMG409	3.83E-1	PMG411	4.00E-1
	SIDON	4.14E-1	RASSHAM	6.14E-1	THEBES	1.07E+0								
PMG416	PMG418	1.02E-1	PMG483	1.15E-1	PMG414	1.38E-1	PMG486	1.38E-1	SAHAB	1.63E-1	PMG408	1.69E-1	JERICHO	1.88E-1
	PMG413	1.88E-1	PMG488	1.88E-1	PMG415	1.91E-1	PMG487	2.03E-1	GIBEON	2.04E-1	PMG485	2.08E-1	BAQ`AH	2.11E-1
	HILLCL	2.25E-1	PMG489	2.50E-1	HEBRON	2.64E-1	PMG410	2.70E-1	AMARNA	2.76E-1	PMG484	2.99E-1	KAHUN	3.00E-1
	BETHSH	3.01E-1	BYBLOS	3.12E-1	ORONTES	3.14E-1	PMG417	3.14E-1	FAYMARL	3.23E-1	DEADSEA	3.25E-1	GAZACL	3.29E-1
	`ARQA	3.29E-1	ASHKEL	3.33E-1	IBNHANI	3.35E-1	LACHISH	3.36E-1	MTOUNE	3.36E-1	BEITMIR	3.39E-1	DABAPAL	3.39E-1
	DABACL	3.59E-1	EBLA	3.66E-1	IFSHAR	3.67E-1	FAQUSCL	3.68E-1	PMG412	3.76E-1	`AJJUL	3.82E-1	FAR`AH	3.83E-1
	FUKHAR	3.95E-1	DABAEG	3.96E-1	APHEK	3.99E-1	KAZEL	4.40E-1	PMG409	4.67E-1	PMG411	4.70E-1	MEGIDDO	4.76E-1
	SIDON	5.09E-1	RASSHAM	6.59E-1	THEBES	1.10E+0								

[1] E-1 and E-2 indicate that the entry should be multiplied by 0.1 or 0.01 respectively. For abbreviated local group names, see text and Fig. 1. Mean Euclidean distances run in decreasing order from left to right in each row, going from top to bottom.

	IFSHAR	2.64E-1	BYBLOS	2.71E-1	PMG413	2.72E-1	MTOUNE	2.77E-1	PMG410	2.80E-1	ASHKEL	2.82E-1	PMG418	2.92E-1
	GAZACL	2.92E-1	PMG415	2.94E-1	`AJJUL	2.98E-1	BETHSH	3.00E-1	DEADSEA	3.00E-1	MEGIDDO	3.02E-1	FAR`AH	3.02E-1
	PMG483	3.02E-1	APHEK	3.05E-1	LACHISH	3.06E-1	PMG485	3.08E-1	KAHUN	3.10E-1	PMG487	3.14E-1	PMG489	3.14E-1
	IBNHANI	3.14E-1	PMG416	3.14E-1	ORONTES	3.14E-1	`ARQA	3.19E-1	FAYMARL	3.22E-1	PMG488	3.26E-1	PMG486	3.27E-1
	HEBRON	3.29E-1	SIDON	3.33E-1	DABAEG	3.33E-1	DABACL	3.35E-1	PMG409	3.36E-1	FAQUSCL	3.42E-1	KAZEL	3.53E-1
	HILLCL	3.61E-1	RASSHAM	4.05E-1	THEBES	1.07E+0								
PMG418	PMG416	1.02E-1	PMG483	1.47E-1	PMG486	1.50E-1	PMG408	1.52E-1	PMG414	1.59E-1	SAHAB	1.65E-1	PMG415	1.91E-1
	PMG488	1.94E-1	JERICHO	2.05E-1	PMG410	2.08E-1	BAQ`AH	2.14E-1	PMG485	2.16E-1	PMG487	2.24E-1	PMG413	2.28E-1
	GIBEON	2.28E-1	KAHUN	2.58E-1	AMARNA	2.62E-1	HILLCL	2.66E-1	FAYMARL	2.68E-1	PMG489	2.71E-1	HEBRON	2.74E-1
	PMG484	2.82E-1	BYBLOS	2.91E-1	PMG417	2.92E-1	`ARQA	3.08E-1	GAZACL	3.12E-1	BETHSH	3.13E-1	ORONTES	3.19E-1
	ASHKEL	3.26E-1	LACHISH	3.29E-1	DABAPAL	3.34E-1	MTOUNE	3.35E-1	DABACL	3.36E-1	IBNHANI	3.40E-1	DEADSEA	3.40E-1
	BEITMIR	3.48E-1	FAQUSCL	3.57E-1	IFSHAR	3.69E-1	FAR`AH	3.70E-1	EBLA	3.71E-1	`AJJUL	3.77E-1	PMG412	3.79E-1
	DABAEG	3.83E-1	APHEK	3.91E-1	FUKHAR	3.91E-1	KAZEL	4.16E-1	PMG411	4.70E-1	PMG409	4.75E-1	MEGIDDO	4.81E-1
	SIDON	5.07E-1	RASSHAM	6.49E-1	THEBES	1.13E+0								
PMG483	PMG486	1.12E-1	PMG416	1.15E-1	PMG418	1.47E-1	PMG414	1.53E-1	SAHAB	1.60E-1	PMG408	1.62E-1	PMG413	1.79E-1
	BAQ`AH	1.86E-1	PMG488	1.92E-1	GIBEON	1.93E-1	JERICHO	1.98E-1	PMG485	2.02E-1	PMG487	2.03E-1	PMG415	2.06E-1
	HILLCL	2.10E-1	PMG489	2.39E-1	HEBRON	2.48E-1	AMARNA	2.63E-1	BYBLOS	2.70E-1	PMG410	2.74E-1	PMG484	2.76E-1
	BETHSH	2.99E-1	PMG417	3.02E-1	`ARQA	3.06E-1	KAHUN	3.10E-1	IBNHANI	3.13E-1	ORONTES	3.25E-1	GAZACL	3.29E-1
	DEADSEA	3.31E-1	EBLA	3.32E-1	MTOUNE	3.33E-1	BEITMIR	3.33E-1	ASHKEL	3.34E-1	DABAPAL	3.34E-1	LACHISH	3.49E-1
	FAYMARL	3.51E-1	PMG412	3.52E-1	IFSHAR	3.55E-1	FAQUSCL	3.69E-1	DABACL	3.71E-1	FUKHAR	3.82E-1	`AJJUL	3.82E-1
	FAR`AH	3.84E-1	DABAEG	3.99E-1	APHEK	4.00E-1	KAZEL	4.09E-1	PMG411	4.38E-1	PMG409	4.48E-1	MEGIDDO	4.56E-1
	SIDON	4.78E-1	RASSHAM	6.11E-1	THEBES	1.11E+0								
PMG484	AMARNA	1.58E-1	JERICHO	1.90E-1	DABAPAL	1.98E-1	PMG417	2.01E-1	SAHAB	2.07E-1	BYBLOS	2.09E-1	PMG412	2.13E-1
	PMG408	2.18E-1	ASHKEL	2.24E-1	GAZACL	2.29E-1	IFSHAR	2.32E-1	PMG415	2.35E-1	EBLA	2.37E-1	GIBEON	2.39E-1
	DEADSEA	2.39E-1	PMG485	2.41E-1	LACHISH	2.43E-1	PMG487	2.43E-1	BETHSH	2.44E-1	BEITMIR	2.50E-1	BAQ`AH	2.52E-1
	PMG488	2.53E-1	KAHUN	2.53E-1	FUKHAR	2.53E-1	FAR`AH	2.59E-1	PMG413	2.60E-1	MTOUNE	2.64E-1	HEBRON	2.69E-1
	PMG489	2.69E-1	`AJJUL	2.73E-1	PMG483	2.76E-1	APHEK	2.78E-1	PMG414	2.82E-1	PMG418	2.82E-1	DABAEG	2.89E-1
	DABACL	2.89E-1	FAQUSCL	2.91E-1	PMG409	2.92E-1	PMG411	2.96E-1	PMG416	2.99E-1	IBNHANI	3.00E-1	PMG486	3.02E-1
	PMG410	3.21E-1	FAYMARL	3.22E-1	MEGIDDO	3.33E-1	KAZEL	3.42E-1	`ARQA	3.51E-1	HILLCL	3.57E-1	SIDON	3.84E-1
	ORONTES	3.98E-1	RASSHAM	4.52E-1	THEBES	1.04E+0								
PMG485	PMG487	3.32E-2	PMG488	6.69E-2	PMG415	9.10E-2	HEBRON	1.16E-1	PMG489	1.23E-1	JERICHO	1.37E-1	AMARNA	1.73E-1
	GIBEON	1.76E-1	KAHUN	1.80E-1	DEADSEA	1.87E-1	PMG413	2.01E-1	SAHAB	2.02E-1	PMG483	2.02E-1	BETHSH	2.02E-1
	BAQ`AH	2.04E-1	PMG416	2.08E-1	PMG418	2.16E-1	GAZACL	2.32E-1	DABAPAL	2.33E-1	LACHISH	2.33E-1	ASHKEL	2.34E-1
	PMG408	2.38E-1	PMG484	2.41E-1	FAYMARL	2.44E-1	BEITMIR	2.44E-1	PMG414	2.47E-1	BYBLOS	2.53E-1	DABACL	2.66E-1
	FAR`AH	2.70E-1	PMG486	2.73E-1	`AJJUL	2.73E-1	IFSHAR	2.73E-1	MTOUNE	2.84E-1	DABAEG	2.91E-1	IBNHANI	2.96E-1
	FAQUSCL	2.96E-1	EBLA	3.04E-1	PMG412	3.04E-1	PMG410	3.05E-1	PMG417	3.08E-1	ORONTES	3.20E-1	APHEK	3.20E-1
	FUKHAR	3.22E-1	HILLCL	3.55E-1	PMG409	3.59E-1	MEGIDDO	3.68E-1	`ARQA	3.83E-1	PMG411	3.90E-1	SIDON	4.16E-1
	KAZEL	4.33E-1	RASSHAM	6.08E-1	THEBES	1.05E+0								
PMG486	PMG483	1.12E-1	PMG414	1.21E-1	PMG416	1.38E-1	PMG418	1.50E-1	PMG408	1.81E-1	SAHAB	1.96E-1	HILLCL	1.97E-1
	BAQ`AH	2.16E-1	PMG413	2.33E-1	GIBEON	2.42E-1	JERICHO	2.46E-1	PMG488	2.53E-1	PMG415	2.53E-1	PMG410	2.60E-1
	PMG485	2.73E-1	`ARQA	2.73E-1	PMG487	2.74E-1	BYBLOS	2.94E-1	PMG489	3.00E-1	PMG484	3.02E-1	AMARNA	3.10E-1
	HEBRON	3.27E-1	PMG417	3.27E-1	IBNHANI	3.39E-1	KAHUN	3.44E-1	MTOUNE	3.48E-1	GAZACL	3.51E-1	ORONTES	3.52E-1
	ASHKEL	3.60E-1	BETHSH	3.61E-1	DABAPAL	3.69E-1	EBLA	3.69E-1	BEITMIR	3.76E-1	LACHISH	3.78E-1	FAQUSCL	3.82E-1
	FAYMARL	3.84E-1	KAZEL	3.88E-1	DEADSEA	3.91E-1	IFSHAR	3.91E-1	DABACL	3.94E-1	PMG412	3.96E-1	FAR`AH	4.09E-1
	FUKHAR	4.10E-1	`AJJUL	4.12E-1	APHEK	4.16E-1	DABAEG	4.22E-1	PMG411	4.81E-1	PMG409	4.98E-1	MEGIDDO	5.01E-1
	SIDON	5.15E-1	RASSHAM	6.38E-1	THEBES	1.13E+0								
PMG487	PMG485	3.32E-2	PMG488	6.95E-2	PMG415	1.01E-1	PMG489	1.16E-1	HEBRON	1.24E-1	JERICHO	1.37E-1	AMARNA	1.76E-1
	GIBEON	1.80E-1	DEADSEA	1.82E-1	PMG413	1.92E-1	KAHUN	2.00E-1	BETHSH	2.02E-1	PMG483	2.03E-1	PMG416	2.03E-1
	SAHAB	2.07E-1	BAQ`AH	2.13E-1	PMG418	2.24E-1	PMG408	2.39E-1	DABAPAL	2.39E-1	ASHKEL	2.42E-1	LACHISH	2.42E-1
	GAZACL	2.42E-1	PMG484	2.43E-1	PMG414	2.46E-1	BEITMIR	2.47E-1	FAYMARL	2.62E-1	BYBLOS	2.67E-1	DABACL	2.72E-1
	PMG486	2.74E-1	IFSHAR	2.78E-1	`AJJUL	2.79E-1	FAR`AH	2.80E-1	MTOUNE	2.87E-1	IBNHANI	2.95E-1	DABAEG	2.96E-1
	FAQUSCL	3.00E-1	PMG412	3.01E-1	EBLA	3.06E-1	PMG417	3.14E-1	PMG410	3.22E-1	ORONTES	3.26E-1	FUKHAR	3.26E-1
	APHEK	3.28E-1	HILLCL	3.52E-1	PMG409	3.58E-1	MEGIDDO	3.70E-1	PMG411	3.89E-1	`ARQA	3.93E-1	SIDON	4.24E-1
	KAZEL	4.44E-1	RASSHAM	6.12E-1	THEBES	1.05E+0								
PMG488	PMG485	6.69E-2	PMG487	6.95E-2	PMG415	1.11E-1	PMG489	1.38E-1	HEBRON	1.47E-1	JERICHO	1.57E-1	AMARNA	1.75E-1
	PMG416	1.88E-1	PMG483	1.92E-1	PMG418	1.94E-1	KAHUN	1.96E-1	GIBEON	2.07E-1	PMG413	2.14E-1	SAHAB	2.19E-1
	BAQ`AH	2.28E-1	PMG408	2.28E-1	DEADSEA	2.30E-1	BETHSH	2.36E-1	PMG414	2.40E-1	PMG486	2.53E-1	GAZACL	2.53E-1
	PMG484	2.53E-1	ASHKEL	2.59E-1	FAYMARL	2.63E-1	DABACL	2.64E-1	LACHISH	2.66E-1	DABAPAL	2.68E-1	BYBLOS	2.77E-1
	BEITMIR	2.86E-1	IBNHANI	2.93E-1	MTOUNE	2.94E-1	FAQUSCL	2.96E-1	FAR`AH	2.99E-1	PMG410	3.01E-1	DABAEG	3.02E-1
	`AJJUL	3.07E-1	IFSHAR	3.12E-1	PMG417	3.26E-1	PMG412	3.30E-1	EBLA	3.30E-1	ORONTES	3.42E-1	APHEK	3.48E-1
	FUKHAR	3.53E-1	HILLCL	3.55E-1	`ARQA	3.86E-1	PMG409	3.96E-1	MEGIDDO	4.07E-1	PMG411	4.24E-1	KAZEL	4.38E-1
	SIDON	4.60E-1	RASSHAM	6.24E-1	THEBES	1.07E+0								
PMG489	PMG487	1.16E-1	PMG485	1.23E-1	PMG488	1.38E-1	PMG415	1.42E-1	HEBRON	1.48E-1	JERICHO	1.83E-1	AMARNA	1.90E-1
	DEADSEA	2.09E-1	GIBEON	2.11E-1	BEITMIR	2.14E-1	IBNHANI	2.14E-1	KAHUN	2.17E-1	GAZACL	2.18E-1	BAQ`AH	2.19E-1
	DABACL	2.21E-1	ASHKEL	2.22E-1	PMG414	2.25E-1	MTOUNE	2.28E-1	DABAPAL	2.32E-1	DABAEG	2.38E-1	FAQUSCL	2.39E-1
	PMG483	2.39E-1	`AJJUL	2.40E-1	SAHAB	2.41E-1	PMG413	2.41E-1	LACHISH	2.46E-1	FAR`AH	2.48E-1	PMG416	2.50E-1
	IFSHAR	2.68E-1	PMG484	2.69E-1	BETHSH	2.70E-1	PMG418	2.71E-1	EBLA	2.85E-1	FUKHAR	2.86E-1	ORONTES	2.90E-1
	FAYMARL	2.92E-1	APHEK	2.94E-1	BYBLOS	2.95E-1	PMG486	3.00E-1	PMG412	3.01E-1	PMG408	3.01E-1	PMG417	3.14E-1
	PMG410	3.22E-1	MEGIDDO	3.29E-1	`ARQA	3.72E-1	PMG411	3.86E-1	PMG409	3.87E-1	SIDON	3.97E-1	HILLCL	3.99E-1
	KAZEL	4.05E-1	RASSHAM	5.81E-1	THEBES	1.08E+0								
HEBRON	PMG485	1.16E-1	PMG487	1.24E-1	PMG415	1.33E-1	PMG488	1.47E-1	PMG489	1.48E-1	JERICHO	1.60E-1	AMARNA	1.81E-1
	DEADSEA	1.81E-1	KAHUN	1.87E-1	GIBEON	1.89E-1	ASHKEL	2.11E-1	GAZACL	2.11E-1	LACHISH	2.18E-1	DABAPAL	2.21E-1
	BETHSH	2.22E-1	BAQ`AH	2.25E-1	SAHAB	2.36E-1	BEITMIR	2.38E-1	BYBLOS	2.44E-1	FAR`AH	2.45E-1	PMG413	2.47E-1
	PMG483	2.48E-1	IFSHAR	2.49E-1	DABACL	2.51E-1	`AJJUL	2.52E-1	MTOUNE	2.59E-1	PMG416	2.64E-1	DABAEG	2.67E-1
	PMG414	2.69E-1	PMG484	2.69E-1	FAYMARL	2.73E-1	FAQUSCL	2.73E-1	PMG418	2.74E-1	PMG408	2.84E-1	IBNHANI	2.85E-1
	APHEK	2.93E-1	EBLA	2.94E-1	FUKHAR	3.09E-1	PMG412	3.18E-1	PMG410	3.21E-1	ORONTES	3.23E-1	PMG486	3.27E-1
	PMG417	3.29E-1	MEGIDDO	3.45E-1	PMG409	3.61E-1	`ARQA	3.76E-1	HILLCL	3.86E-1	PMG411	3.96E-1	SIDON	4.00E-1
	KAZEL	4.06E-1	RASSHAM	5.97E-1	THEBES	1.05E+0								

Transjordan form clusters at the middle and bottom parts of the diagram. Although it can be seen that these jars are close to one another in MED space, very little more information about their relationships to defined local groups can be derived from this representation of the data. Because of the inherent limitations of a two-dimensional projection of points in multidimensional space, it is important to confirm the "results" from a dendrogram by examining the actual distance matrix on which the dendrogram is based (see Table 4). There, Hill Country, Jordan Valley, and Transjordian local groups are bunched near the beginning of the listing for every Abydos jar. The modern Hebron clay group, which matches the largest number of Abydos jars, is included at the end of the chart.

2. Brief overview

The significance of the fact that the Syro-Palestinian type jars in Tomb U-j probably contained a resinated wine, flavored with fig, is discussed in detail in appendix 1. NAA enabled the origins of the jars to be determined, and it is a reasonable assumption for this proto-historic period that the wine, which the jars contained, was produced in the same regions.

In brief, none of the jars tested was chemically close to any clay or ancient pottery sample outside of the coastal and hill country regions of southern Palestine, the Jordan Valley, and Transjordan. Thus, while NAA was carried out for only a small proportion of the Abydos jars, the results point uniformly to regions of Palestine where earlier (Chalcolithic) and contemporaneous archaeobotanical evidence exists for grapevine transplantation and eventual larger scale production of wine. A clay sealing, composed of Nile alluvial clay, indicates that, before the jars were deposited in tomb U-j, a final stoppering and sealing process took place in Egypt. "Registration" of the jars might have taken place at Abydos, in keeping with the formalities of a royal burial, or at a site in the Delta where the wine entered Egypt before being transported to the south.

THE ORGANIC CONTENTS OF THE TOMB U-j SYRO-PALESTINIAN TYPE JARS: RESINATED WINE FLAVORED WITH FIG

By Patrick E. McGovern, Donald L. Glusker, and Larry J. Exner[*]

Three of the Abydos jars from chambers 7 and 10 were tested for organic compounds, viz., excavation nos. 7/18 (Cat. no. 1), 10/22 (Cat. no. 80), 10/115 (Cat. no. 156; NAA no. PMG417, see P. E. McGovern in Appendix 2, and Table 1). The targeted compounds were tartrate/tartaric acid (characteristic of grape products, including wine) and the terpenoids of tree resins. The archaeochemical laboratory of the Museum Applied Science Center for Archaeology (MASCA) of the University of Pennsylvania Museum employs complementary analytical techniques – infrared spectrometry (IR), liquid chromatography, and wet chemical analyses – to determine the presence/absence of these and other organics[1].

After the sand filling had been removed from the jars, rings of a yellowish/brownish flaky residue, which were slanted off from the horizontal, were seen on the interiors (e. g. Pl. 84, no. 389). They are best interpreted as the remains of a liquid that had gradually evaporated, with materials on the surface of the liquid agglomerating to form the rings.

1. Chemical preparation of the samples

The yellowish/brownish flaky residue inside the three jars was largely calcium carbonate, because it readily dissolved in weak hydrochloric acid (HCl) with vigorous bubbling, to give light yellowish solutions. When evaporated to dryness, the material from jar nos. 7/18 and 10/22 had a very pungent, even vile odor, such as is characteristic of long-chained fatty acids. By contrast, the flaky residue inside jar no. 10/115 yielded a material which smelled of caramelized sugar.

The residue inside jar no. 10/22 differed from the others in being visibly heterogeneous. A very fine brownish fraction dissolved in HCl without bubbling, and, when evaporated to dryness, had no odor. Numerous small brownish, semi-transparent particles and a few transparent brown flakes could be separated from the bulk of the residue. When treated with weak hydrochloric acid, the interiors of the particles dissolved, without bubbling, and yielded a deep yellowish solution; the exteriors of the particles remained as dark reddish to black shells, which collapsed, when touched, to a gummy residue.

The solids that remained after acid treatment and evaporation to dryness were then extracted with methanol using an ultrasonicator (two 20-min periods), evaporated to dryness, and analyzed by diffuse-reflectance Fourier-transform IR spectrometry and high-performance liquid chromatography (HPLC).

2. Infrared spectrometric results

Diffuse-reflectance IR is a versatile technique, which has the advantage that very little material is required (1–10 mg) and, unlike transmission IR spectrometry, an optically transparent potassium bromide wafer does not have to be prepared. A Nicolet 5DXB instrument, with a 20DX data processor, was used in taking measurements at 4 cm^{-1} resolution. Spectra were then deresolved at 8 cm^{-1} for library storage, searches, and printing.

The IR spectra of residues from jar nos. 7/18 and 10/115 (Fig. 1) clearly show the presence of calcium tartrate, along with a hydrocarbon component. By comparing the IR spectrum of synthetic calcium tartrate with the Abydos jar residue spectra, it can be seen that medium intensity absorption bands in the 1550–1650 cm^{-1} range coincide. Other bands, characteristic of calcium tartrate, at 3442, 1385, 1275, 713, 596, and 555 cm^{-1} also support this interpretation. The broad absorption band centered at about 3400–3350 cm^{-1} results from water of hydration. The hydrocarbon stretch bands near 2920 and 2850 cm^{-1} point to another component, in addition to calcium tartrate, which was identified as a tree resin by the liquid chromatographic analyses (below).

Although characteristic absorptions bands for calcium tartrate are present, the IR spectrum of the flaky residue from jar no. 10/22 has hydrocarbon absorptions with magnitudes that are markedly less than those of the other two jars (see Fig. 1). Moreover, the sharp, intense absorptions at 1630, 1452, 1427, 1368 and 1348 cm^{-1} in the 10/22 residue are correlated with the methanol-insoluble fraction of a modern red wine (Fig. 1), and are most likely due to polyphenolic aromatic compounds, such as tannins and anthocyanins that give wine most of its color and taste. As also seen in Fig. 2, these compounds were concentrated in the numerous gummy particles of jar no. 10/22 residue, although they are also detectable in the bulk residues of 7/18 and 10/115.

3. Liquid chromatographic results

Comparable methanol extracts of the jar residues were also analyzed by HPLC. Samples were run at ambient temperature on a 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. 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. All the Abydos jar samples showed a sharp early peak at about 1 min retention time, and a second peak composed of several overlapping, unresolved peaks starting about 1.4 min and finishing at about 1.7 min (Fig. 2). The ultraviolet spectrum of the main flaky fraction of three jars is very similar to that of calcium tartrate at the same retention time (1.64 min), as seen for jar no. 10/22 in the right-hand inset to Fig. 2, thus confirming the identification by IR (above). In the left inset, the ultraviolet spectra of the same sample is compared to a sample of terebinth tree resin (*Pistacia atlantica* Desf.) from the 14^{th} century B.C. Uluburun shipwreck[2] (Kaş no. 215) at a retention time of 1.54 min. In combination with the marked IR hydrocarbon absorptions of the methanol extracts from jar nos. 7/18 and 10/115, this tree resin is best supported by the HPLC data as compared with other resins (e. g., pine, myrrh, and frankincense) in our database. Terebinth tree resin is predominantly comprised of triterpenoid compounds[3].

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[1] P. E. McGovern/R. H. Michel, in: P. E. McGovern/S. J. Fleming/S. H. Katz (eds.), *The Origins and Ancient History of Wine*, Luxembourg 1995, pp. 57–65; P. E. McGovern/M. M. Voigt/D. L. Glusker/L. J. Exner, in: *Nature* 381, 1996, pp. 480–481.

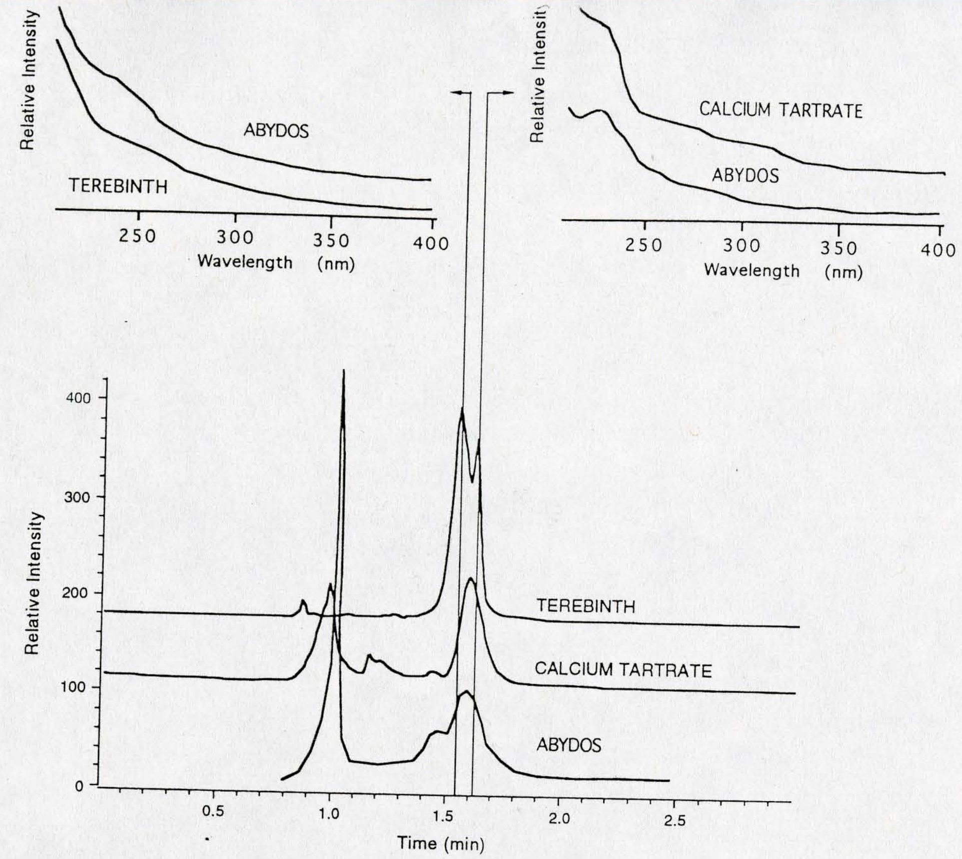

Fig. 1 Diffuse-reflectance Fourier-transform infrared spectra of the flaky residue inside three Tomb U-j jars (nos. 7/18, 10/115, and 10/22), gummy particles from jar no. 10/22 after separation from the flaky residue and hydrochloric acid treatment, the methanol insoluble fraction of a modern red wine, and synthetic calcium tartrate.

4. Chemical spot test results

A third analytical technique also confirmed the presence of calcium tartrate in the flaky residues of the three Abydos jars. In a specific, wet-chemical test[4], β,β'-dinaphthol and concentrated sulfuric acid are used to convert tartaric acid/tartrate to a compound that exhibits a characteristic green fluorescence under UV light. Ground-up portions of the flaky residue from each jar, when treated with the test reagents, gave positive results.

5. Discussion

The chemical attestation of calcium tartrate inside three of the Abydos jars in chambers 7 and 10 provides strong evidence that these jars, and probably many of the other Syro-Palestinian type jars from the tomb, contained wine. The

[2] C. Pulak, in: *AJA* 92, 1988, pp. 1–37; G. F. Bass/C. Pulak/D. Collon/J. Weinstein, in: *AJA* 93, 1989, pp. 1–29.

[3] J. S. Mills/R. White, in: *Archaeometry* 31, 1989, pp. 37–44 (hereafter abbreviated as Mills/White, *Resins from Uluburun*).

[4] F. Feigl, *Spot Tests in Organic Applications*, New York 1954, p. 261.

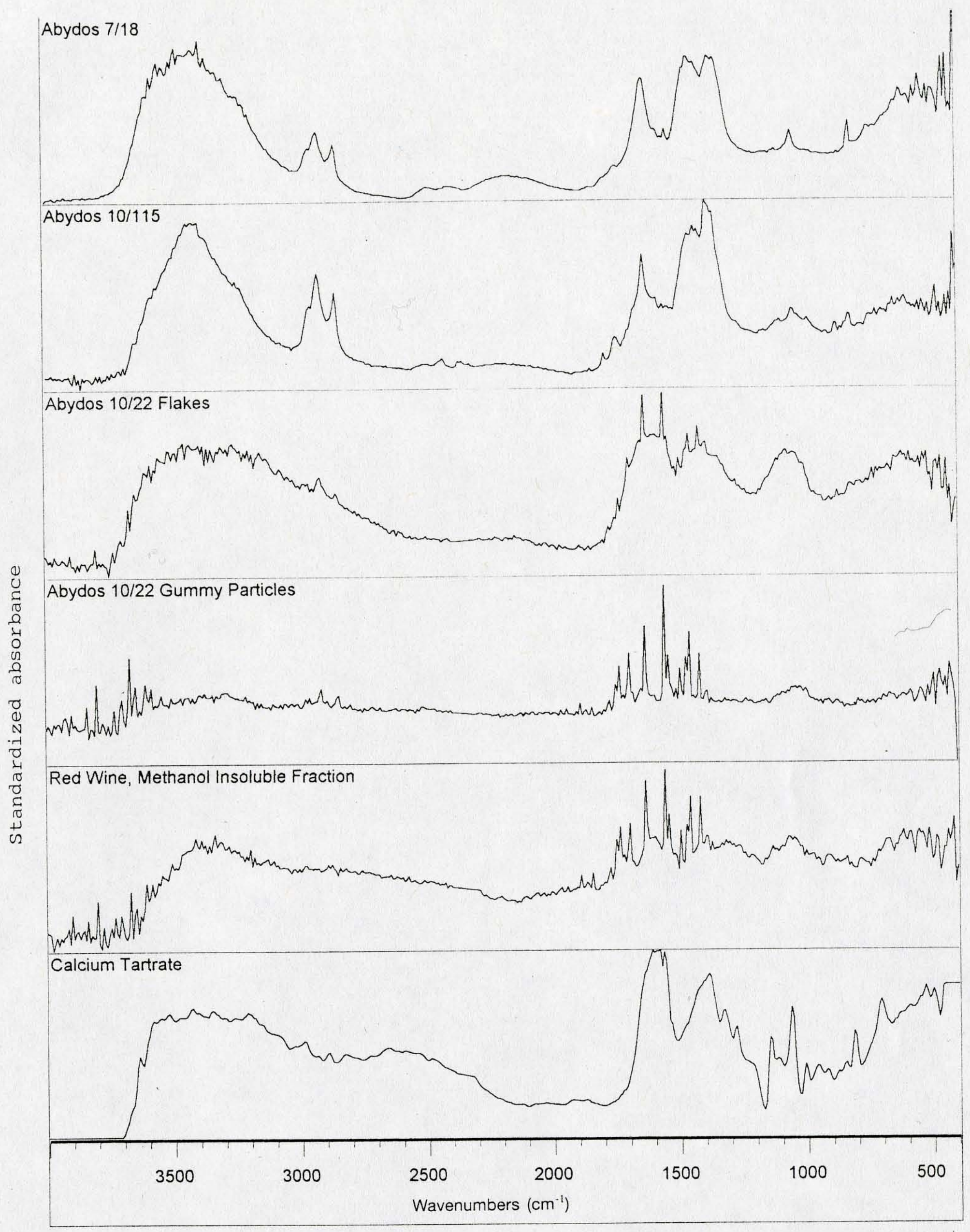

Fig. 2 High-performance liquid chromatogram of a methanol extract of the flaky residue inside Tomb U-j jar no. 10/22, which is similar to the other two jars (nos. 7/18 and 10/115). Chromatograms of terebinth tree resin (*Pistacia atlantica* DESF.) and synthetic calcium tartrate are shown for comparison. The ultraviolet spectra at a retention time of 1.64 min (right-hand inset) indicates the presence of tartrate, a principal component of grape wine; those at 1.54 min (left inset) are correlated with terebinth tree resin.

insoluble calcium salt of tartaric acid would readily form in the calcareous environment of the site. Since tartaric acid occurs in large amounts in the Middle East only in grapes, the liquid in the jars must derive from a grape juice. Under normal conditions and at room temperature, the natural yeast on some grape skins quickly ferments the juice to wine. Slow pressing methods in antiquity and high temperatures in the Middle East also contributed to rapid fermentation, which probably began even before the liquid went into the jars. Since it is probable that an organic cover made of leather or cloth was fitted over the jar mouths, tred with string and sealed, the wine would haver been less likely to turn to vinegar.

The HPLC results pointed to another component of the residues that make it virtually certain that the Abydos jars originally contained wine[5]. The addition of terebinth tree resin to wine, in the fashion of modern *retsina* (which now contains either pine[6] or sandarac resin[7]), served in part to disturb and inhibit the growth of bacteria (*Acetobacter*) that

[5] *AEMI* 4, pp. 16–18.

[6] An ancient pine-resinated wine of 5th century B.C. Italy is chemically characterized by E. HOSTETTER/C. W. BECK/D. R. STEWART, in: *Studi Etruschi* 59, 1994, pp. 211–225.

[7] For this resin, which derives from a northwestern African tree (*Tetraclinis articulata*), see *AEMI* 4, pp. 321, and 358–359.

convert wine to vinegar, besides masking any offensiveness of taste and smell[8]. Wine and tree resins figure importantly in the Egyptian pharmacopoeia, since both have anti-microbial properties[9]. 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[10] and COLUMELLA[11] wrote about it in the 1st century A.D.

Terebinth resin has been described as the "queen of resins" and "one of the most persistent drugs in history"[12]. 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[13]. The terebinth tree has been and is widespread and abundant in the Middle East[14], 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.[15] In recent times, it has been used to make chewing gum in Greece[16] and to prepare perfume in the eastern desert of Egypt.[17] Its "turpentine" odor 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.

The chemical confirmation of wine in many of the Syro-Palestinian type jars in Tomb U-j was further corroborated by archaeobotanical investigation (see appendix by F. FEINDT, S. 391 ff.). To recapitulate, 47 of 207 jars contained grape pips, generally between 20 and 50 each, and several completely preserved grapes were also recovered. Eleven vessels had remains of sliced figs, which had been perforated, strung together, and probably suspended in the liquid. Although a fig additive is otherwise unattested in ancient Near Eastern and Egyptian wine, it might have served as a sweetening agent or for special flavoring; by cutting up and stringing out the fig segments, more of the wine would come in contact with the fruit. Fresh, whole grapes were probably added for the same reasons. Figs, like grapes, are also an excellent source of yeast for natural fermentation. The presence of tartaric acid or its calcium salt in the chemical analyses was not dependent on the presence of grape remains, since one sample tested was from a jar that yielded only fig seeds and a second sample was from a jar with no archaeobotanical materials.

With an average volume of 6 to 7 litres for each of the projected 700 wine jars in tomb U-j, the king could have drawn upon some 4500 litres in his afterlife. Where had such a large quantity of wine been produced? Abydos, located almost 400 miles up the Nile in an extremely dry terrain, did not support vineyards during this period. In the Nile Delta, grape remains of predynastic and Early Dynastic date are thus far very sparse, having been confirmed only for Buto[18] in the central Delta and Tell Ibrahim Awad to the east[19]. The stoppered and sealed "wine jars" found in Dynasty 1 and 2 cemeteries at Abydos and Saqqara, which are of Egyptian type and made of Nile alluvial clay, suggest that a native Egyptian winemaking industry had begun to develop by this time, but the Abydos jars predate this period.

Since the wild grape never grew in Egypt, is it possible to know when the first grapevines were transplanted to the Nile Delta? The answer to this question is vital for understanding the prehistory of an industry that eventually spread over the entire Delta, to the large western oases, and even to towns on the upper Nile where the climate would seem to preclude viniculture. Moreover, it has far-reaching implications for the consolidation of one of the earliest literate civilizations. The domesticated grapevine could only have come from some region of the Levant that was already exploiting it, and many specialists – farmers/ horticulturalists, transporters/traders, pottery-makers, and, above all, vintners – would have been involved in and essential to the establishment and success of the developing industry. The grapevine hieroglyph itself, showing a grapevine trained to run along a trellis or arbor, indicates that the Early Dynastic viniculture was quite sophisticated.

Neutron Activation Analysis (NAA) of 18 Syro-Palestinian type jars from Tomb U-j (see Appendix 2) constituted a major step forward in understanding how viniculture might have been transferred from Palestine to Egypt. As discussed elsewhere in this monograph, the Abydos wine jar corpus is dominated by bottle-shaped jars with narrow mouths, which would have been easier to stopper and better suited to long-distance trade. Differences in fabric, shape, decoration, and other features suggest that they originated from more than one place. The best typological parallels, especially for the handled jars, are examples from greater Palestine: Tel ʿErani in the southern coastal plain, Lachish in the nearby lowlands, Megiddo in Jezreel Valley, Jericho in the Jordan Valley, Bab edh-Dhra on the eastern shore of the Dead Sea, and Lehun on the southern Transjordanian plateau. How-

[8] G. G. MAJNO, *The Healing Hand: Man and Wound in the Ancient World*, Cambridge 1975, pp. 64, 124, and 210–225 (hereafter abbreviated as MAJNO, *Healing Hand*); A. TCHERNIA, 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, pp. 65–74.

[9] L. GRIVETTI/L. H. LESKO, in: P. E. MCGOVERN/S. J. FLEMING/S. H. KATZ (eds.), *The Origins and Ancient History of Wine*, Luxembourg 1995, pp. 9–22 and 215–230, respectively. Also see MAJNO, *Healing Hand*, pp. 186–188, and, most recently, M. E. WEISSE, ET AL., in: *British Medical Journal* 311, 1995, pp. 1657–1660.

[10] PLINY the Elder, *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".

[11] COLUMELLA, *De re rustica*, 12.19–20.

[12] MAJNO, *Healing Hand*, pp. 64 and 210.

[13] P. E. MCGOVERN/U. HARTUNG/V. R. BADLER/D. L. GLUSKER/L. J. EXNER, in: *Expedition* 39, 1997, pp. 3–21; P. E. MCGOVERN/M. M. VOIGT/D. L. GLUSKER/L. J. EXNER, in: *Nature* 381, 1996, pp. 380–381; P. E. MCGOVERN, in: *The Sciences* 36, 1996, pp. 27–31.

[14] M. ZOHARY, in: *Palestine Journal of Botany, Jerusalem Series* 5, 1962, pp. 187–228.

[15] MILLS/WHITE, *Resins from Uluburun*, p. 38; A. LUCAS, in: *ASAE* 33, 1933, pp. 187–189; *AEMI* 4, p. 324, identified 50 kg of a resin inside a sarcophagus as that of *Pistacia atlantica*.

[16] MILLS/WHITE, *Resins from Uluburun*, p. 38

[17] M. E. KISLEV, in: *PEQ* 117, 1985, pp. 134–138.

[18] U. THANHEISER, in: *Ägypten und Levante* 2, 1991, pp. 39–45.

[19] U. THANHEISER, personal communication.

ever, exact parallels for the bottle-shaped jars that lack handles do not occur in Early Bronze Age I Palestinian assemblages (ca. 3300–3000 B.C.), which are contemporaneous with the Abydos tomb. Possibly, this absence is due to the relatively small number of sites that have been excavated in the southern hill country of Palestine and in Transjordan. One might also propose that a specialized trade in wine would demand a special container that would therefore be found at relatively few sites.

To summarize the NAA results (see appendix 2), no identifiable Egyptian clay was used to make the jars. The 18 jars tested all came from Palestine: 1 from southern Palestine (the coastal region extending into the lower Shephelah), 5 from the southern Hill Country, 4 from the Jordan Valley, 4 probably from northern Transjordan, 2 from central Transjordan, and 2 from southern Transjordan. While the NAA study represents a small proportion of the jar corpus, the results point uniformly to a region of Palestine where earlier (Chalcolithic) archaeobotanical evidence exists for grapevine transplantation and presumably larger scale production of wine. In Early Bronze Age I, only these specific areas of Palestine have yielded what have been classified as domesticated grape pips and berries, namely, ᶜEn Besor near Gaza, Jericho in the southern Jordan Valley, Bab edh-Dhra on the eastern shore of the Dead Sea, and Jawa in northern Transjordan[20].

One of the clay sealings associated with the Abydos jars was also analyzed by NAA, and it was found to be composed of Nile alluvial clay. This finding indicates that before the jars were deposited in tomb U-j a final stoppering and sealing process took place in Egypt, perhaps at Abydos or, alternatively, at a site in the Delta where the wine entered Egypt before being transported to the south.

A two-stage process in the Early Bronze I interactions between Egypt and Palestine may be proposed to account for the Abydos wine jars and the start of a native winemaking industry shortly thereafter. In the first phase, increasing Egyptian demand for horticultural products, especially grapes/wine and perhaps olive oil, spurred trade in these goods. Cultivation of the fig, one of the additives in the Abydos wine jars, had probably also had begun in Palestine by this time. Once a market for wine had developed in Egypt, a second stage of interaction was possible: the transplantation of grapevines to the Delta and the production of wine, probably under the tutelage of foreign specialists.

[20] Zohary, *Domestication of Vitis Vinifera*, p. 28; L. E. Stager, in: J. N. Tubb (ed.), *Palestine in the Bronze and Iron Ages*, London 1985, pp. 172–188.