SOME RHODIAN AMPHORA CAPACITIES

(Plate 80)

THAT PLAIN GREEK WINE AMPHORAS came in standard sizes is a familiar idea. From the 1930's on surviving specimens have been measured in order to find the standards of the series to which they belonged.[1] Information about the changes in Chian amphoras after the Standards Decree, for example, has contributed both to the economic and to the political history of the Athenian Empire.[2] The jars of Hellenistic Rhodes have long seemed promising candidates for study; measurable examples are numerous, and most have the stamps of the eponymous magistrate of the year and of the fabricant on the handles.[3] Virginia Grace measured capacities of Rhodian amphoras at the Agora Excavations in Athens in 1939 and subsequently in Cyprus, in Sarasota Springs (Florida), in Rhodes, and elsewhere; during the last few years we have worked with her. Three recent finds and

[1] Virginia Grace encouraged us to study amphora capacities and has been unstinting with information and other help; much of the material in this paper is hers, including all amphora dates (cf. footnote 7 below), the photographs (Pl. 80; descriptions, p. 320), and most of the capacity figures for the Villanova jars (cf. Appendix 2), and she should on any other occasion have been senior author. She addressed herself long ago to the general field of Greek amphora standards, to one corner of which we address ourselves here, in "Standard Pottery Containers of the Ancient Greek World," *Hesperia*, Suppl. VIII, pp. 175–189.

Carolyn G. Koehler began the study of capacities with us, and with her and Barbara L. Johnson we have a paper, "Measuring Amphora Capacities," submitted to *JFA*, that provides much of the basis for this one, of which they have also kindly, and thoroughly, criticized a draft. Dr. Yiannis Papachristodoulou, the Ephor of Antiquities for the Dodecanese, and his staff made our work in Rhodes possible with much generosity; we are grateful to them for the opportunity to publish information about the large number of Rhodian amphoras in their splendid collection. Demetrios Mouliates, Roussos Angelinakes, Mikhales Kostas, and Claire Zimmerman were stalwart assistants. Michael and Susan Katzev provided not only information about the Kyrenia wreck but benevolent scepticism. Drs. David Jordan and Dugald Matheson helped with theory and practice; we are also grateful to Drs. David Smith of the Department of Rehabilitative Medicine in the University of Toronto and John Oakley of William and Mary College for advice.

Works frequently cited are abbreviated as follows:

Brashinsky, 1978	= I. B. Brashinsky, "Standards of Rhodian Amphoras," *KSIA* 1978, pp. 11–16
Délos XXVII	= V. Grace and M. Savvatianou-Petropoulakou, "Les timbres amphoriques grecs," *Exploration archéologique de Délos* XXVII, Paris 1970, pp. 277–382
Grace, 1949	= V. Grace, "Standard Pottery Containers of the Ancient Greek World," *Hesperia*, Suppl. VIII, *Commemorative Studies in Honor of Theodore Leslie Shear*, Princeton 1949, pp. 175–189
"Measuring"	= B. L. Johnson, C. G. Koehler, P. M. Wallace Matheson and M. B. Wallace, "Measuring Amphora Capacities," submitted to *JFA*

[2] See *Délos* XXVII, pp. 359–360; V. R. Grace, "Exceptional Amphora Stamps," *Studies in Classical Art and Archaeology*, G. Kopcke and M. B. Moore, edd., Locust Valley, N.Y. 1979, pp. 121–122; cf. "Measuring", notes 8–10.

[3] As long ago as 1873 A. Dumont (*RA* 25, 1873, p. 326) commented on their uniformity and urged capacity measurements, and the Ῥόδια (*κεράμια*) mentioned in papyri were early taken as of standard contents, e.g., by U. Wilcken, *Griechische Ostraka aus Aegypten und Nubien* I, Leipzig and Berlin 1899, p. 765. See subsequently Grace, 1949, p. 180, *Délos* XXVII, pp. 279, 298; Brashinsky, 1978, pp. 11–16, and C. Diez, "À propos des amphores commerciales rhodiennes," *Revue des archéologues et historiens d'art de Louvain* 13, 1980, pp. 24–49, esp. 26–27, 34.

one older one from *ca.* 300–200 B.C. have allowed us to study the capacities of Rhodian amphoras of this period in some detail.

In brief, the Rhodian wine amphora apparently had a mean capacity in trade of not over 25½ liters at about 300 B.C. (e.g., amphoras from the Kyrenia shipwreck), about 26½ liters in the 230's (Hôtel de Soleil deposit), about 25½ liters 20 years later (Kleisimbrotidas–Theuphanes group), and over 24½ liters at around 200 B.C. (Villanova find). Scattered evidence suggests that by the middle of the 2nd century the mean had risen substantially, to about 26½ liters. These changes in the mean, however, seem too frequent and too small to be explained as deliberate changes of standard (e.g., from the "Attic" to the "Ptolemaic") or of denomination (e.g., from nine *choes* to eight *choes*) or of both. We hypothesize that the mean fluctuated in practice in the way in which the striking weight of successive issues of a single denomination of a coin series on a single standard often fluctuates.[4] In the wine trade some, for instance, vintners, stood to gain from unofficial decreases in the mean size of container; others, for instance, consumers, stood to lose. We interpret the variations in capacity of the amphoras as reflecting the conflict between such interests.

We first set out our information group by group and then elaborate our interpretation; points of method and lists of findings are detailed in the appendices below. All figures given in the tables are of contents of jars filled to the brim, and no allowance has been made for lining with pitch (but see p. 296 below) or for stoppering in commerce.[5] In the summary above and in the discussion, about three quarters of a liter is rather arbitrarily deducted from the means to represent lining and stoppering.

A. Maiuri excavated the most valuable group of jars at Villanova, near the present Rhodes airport; they had been planted, possibly to make a fence, some in a long row, others resting on them.[6] In 1949 Virginia Grace took the capacities of the 50 Rhodian specimens that were measurable with water; 19 had the eponym *Kratidas* and the fabricant *Diskos*; 11 had *Hieron* and *Diskos*; 6 had *Xenophanes* and *Diskos*; 3 had *Pratophanes* and *Diskos*; 6 had other pairs; 5 lacked one or both stamps. The four eponyms mentioned date years very close to 200 B.C.[7] In 1979, 1980, and 1981 some remeasurements were made. Single water measurements of a jar are subject to various sorts of error; we state them only to the nearest 50 ml., and readers should attach a mental ± 100 ml. even for comparative purposes inside a group (see Appendix 1). Nevertheless, even a dozen such figures establish the mean of a

[4] Thus of six issues of Euboian League drachms of about 3¾ gm., the second two have a standard ⅛ gm. (*ca.* 3%) higher than the first two, the fifth is nearly ¼ gm. (*ca.* 6%) lower than the fourth, and the sixth is almost back to the standard of the first two; W. P. Wallace, *The Euboian League and its Coinage*, Numismatic Notes and Monographs 134, New York 1956, table opposite p. 118.

[5] For brief discussions of lining to prevent evaporation of wine through the porous clay and of stoppering see "Measuring", notes 13 and 14. The figures are systematically a little low (up to 75 ml.) because of absorption of water during measuring (Appendix 1, p. 302).

[6] A. Maiuri, "Una fabbrica di anfore rodie," *ASAtene* 4–5, 1921–1922, pp. 249–269; cf. V. Grace, "Stamped Amphora Handles found in 1931–1932," *Hesperia* 3, 1934, pp. 216–217; *Délos* XXVII, pp. 294–295.

[7] Virginia Grace's current datings of Rhodian eponyms are discussed briefly in "Revisions in Early Hellenistic Chronology," *AthMitt* 89, 1974, pp. 193–200.

group quite reliably to the nearest 0.1 liter. The main conclusion about the Villanova jars made by Diskos is very simple, as Table 1 illustrates.

Table 1. Capacities of Diskos' Jars at Villanova[8]

Eponym	*Condition*	*Number*	*Range in ml.*	*Mean* ± *1 S.D. (mls)*
Kratidas	Intact	13	24,800–26,200	25,408 ± 435.9
	Supplemented	6	24,600–26,650	25,398 ± 806.6
	Total	*19*		*25,405 ± 554.5*
Hieron	Intact	5	24,850–26,550	25,320 ± 712.0
	Supplemented	6	24,050–26,600	25,400 ± 882.6
	Total	*11*		*25,355 ± 786.9*
Xenophanes	Intact	5	24,450–26,650	25,770 ± 1,075.1
	Supplemented	1	————————	25,750
	Total	*6*		*25,767 ± 961.6*
Pratophanes	Intact	1	————————	25,350
	Supplemented	2	25,450–25,900	25,675
	Total	*3*		*25,567 ± 293.0*
All together		39	24,050–26,650	25,459 ± 665.0
All except VG R 72		38	24,450–26,650	25,496 ± 630.6

The mean of our gross capacity figures for jars of Diskos in the four years listed is, then, approximately 25.5 liters.[9] As all the jars are without linings and measurements were taken to the brim, the actual amount of wine contained in a lined and stoppered jar used for

[8] The capacities used are basically the 1949 results of Virginia Grace adjusted as defined in Appendix 2 and listed in Table 9. "Supplemented" capacities are those for jars with chips, cracks, or even pieces missing that cannot be filled with water beyond a certain point in the neck. Assuming a cylindrical neck, as the interior diameters we have measured average *ca.* 0.047 m., the unfilled volume is *ca.* 0.693 (πr^2) times the vertical distance left unfilled below the rim. Adding this figure to the amount of water measured in fact produces capacities very close to those of intact jars (as the table shows, the mean capacity of 13 intact and 6 "supplemented" jars of Diskos in the year of Kratidas are only 10 ml. apart).

1 S.D. (Standard Deviation) is the range within which it may be assumed on statistical grounds that the capacities of 68% of all similar jars (i.e. made by the same potter in the same year) will fall. This test may be applied only where three or more samples are present in a group.

[9] There is no significant difference as determined by the Student's *T*-test between the means of the capacities of any pair of the four groups Diskos–Kratidas, Diskos–Hieron, Diskos–Xenophanes, Diskos–Pratophanes. In addition to Diskos' jars, 11 others were measurable (all are listed in Table 9). The eight that had one of the same four eponym stamps or no eponym stamp surviving were all within the range of the Diskos jars (although VG R 2 was smaller than all but VG R 72). The three jars with stamps of (considerably) earlier eponyms had slightly greater capacities; they need have no more intrinsic connection with the bulk of the lot than do the few non-Rhodian jars also found in it. That the three capacities dissociate their jars from the others and that Virginia Grace's arrangement of eponyms gives them an earlier date on other grounds confirms in a small way the validity of both sorts of argument, and ours, as much the more conjectural, with greater force.

Apart from Diskos there is most evidence for Aristos. As well as the two jars with capacity measurements (see Table 9), four others were well enough preserved for the diameter to be measured; the mean of the six diameters is 0.353 m. The three jars of which it was possible to measure the original height have a mean of 0.80 m. These figures help to show that Aristos' jars were generally somewhat larger than Diskos'. (See also footnote 25 below.)

commerce would have been distinctly less (footnote 5 above), say, somewhat over 24½ liters on average. All the jars but one fall within 1.1 liters on either side of 25.55 l., and the linear dimensions also vary very little; maximum diameters range from 0.340 to 0.356 m., heights from 0.765 to 0.792 m. (VG R 72, with a small diameter, 0.336, and a correspondingly small capacity, 24,050 ml., has been excluded). The close results surely confirm that a standard capacity was aimed at and pains taken to achieve it with each jar.[10]

We have data also from three other find-groups of Rhodian amphoras from *ca.* 300–200 B.C. From the Kyrenia shipwreck of about 300 B.C., 23 jars (21 of them unstamped) were weighed empty and then filled with water to the brim and reweighed by Susan and Michael Katzev, who have very kindly allowed us to make brief mention of their results in advance of further study and publication (cf. also below, footnote 20). Table 2 shows that most of, but not all, the specimens fell within a 2¼-liter range. The jars mostly still have much of their pitch lining; there is no evidence for the stoppering.

Table 2. Capacities of Kyrenia Jars

Number	*Range*	*Mean*
23 (total)	20.4–28.8 liters	25.65
22	23.1–28.8 liters	25.88
18	24.75–27.0 liters	25.90

On 137 jars found during construction at the Hôtel de Soleil in the city of Rhodes[11] almost all the eponym stamps (123) named *Pausanias* (*ca.* 240–230) and the fabricant stamps *Damonikos*, *Kreon*, *Mikythos*, or *Xenotimos*. As they had been stood upside down in rows and all had breaks at least in the neck when found, we measured those that were substantially complete after mending but without restoration, using polystyrene pellets. Since single polystyrene measurements are not as accurate as single water measurements (Appendix 3), additional caution is needed in using the results. (See the detailed discussion of Hôtel de Soleil results in Appendix 4.) The jars showed no sign of lining; there was no evidence for the stoppering. Table 3 reports the 123 jars of the four main fabricants.

The range of capacities is discussed in Appendix 4; we may summarize it in either of two ways. The smallest jar of the 123 held *ca.* 25.4 l. and the largest *ca.* 29.9 l. (both are Kreon's, cf. footnote 43 below), a range of 4½ liters, and there were two yet smaller jars in the total batch of 134 jars measured (see footnote 44 below), extending the range to 6⅓ liters. At the same time only 10 of the 123 jars of the four main fabricants are definitely

[10] Many of Diskos' jar handles, although none from the year of Hieron, bear an early form of secondary stamp (*Délos* XXVII, pp. 294–295), but this seems unrelated to capacity, for the 10 intact and 3 supplemented jars from the year of Kratidas that have it include the two with the smallest and the largest capacities for the eponym-fabricant pairing and five within a quarter of a liter of the mean. For an illustration of a secondary stamp on a jar in the year of Kratidas, cf. Pl. 80:c.3.

[11] The find is reported briefly in Ἔργον 1960, p. 201 (cf. *Délos* XXVII, p. 301). The jars are now housed in a room at the Ephoreia on Rhodes, and each carries two identification numbers: an A number, the inventory number assigned by the Ephoreia, and a ΜΣ number (previously assigned for Virginia Grace's records in Athens). Both numbers are given below when a jar is cited individually. The careful work of the excavators and the conservators at the Ephoreia (undertaken years ago with no reference to this study) included an enviable maximum of mending as opposed to restoration, and no avoidable distortions seem to have been introduced (in particular, no interior plaster was used).

Table 3. Capacities of Hôtel de Soleil Jars of the Year of Pausanias

Fabricant	*Number*	*Mean in liters*
Damonikos	48	26.9
Kreon	16	27.2
Mikythos	31	27.8
Xenotimos	28	27.6
Together	123	27.3

more than 1¼ liters above or below the mean for the fabricant, so that a given pottery on the whole kept its jars within a range of *ca.* 2½ liters.

The range of linear dimensions of the Hôtel de Soleil jars shows less obvious divergence among fabricants than the ranges of capacities.[12] For Damonikos, Kreon, and Mikythos, interior heights, that is, depths, run from 0.702 to 0.749, with 82 of the 95 between 0.706 and 0.739 and a norm of 72¼ cm. (73 for Mikythos), and maximum diameters run from 0.355 to 0.377, with 90 of the 95 between 0.355 and 0.373 and a norm of 36½ cm.[13] For Xenotimos, depths run from 0.687 to 0.720, with 26 of the 28 between 0.695 and 0.720 and a norm of 70¾ cm., and maximum diameters run from 0.358 to 0.376, with 26 of the 28 between 0.360 and 0.375 and a norm of 36¾ cm. Xenotimos' jars are then on the average slightly shorter and broader than the rest, and they may be characterized as slightly more old-fashioned in profile. Xenotimos also has all his jars within a three-liter range and all but two within two and one-half liters.

Compare with the Kyrenia and Hôtel de Soleil jars 12 jars with fabricant stamp Kleisimbrotidas and eponym stamp Theuphanes dating *ca.* 215–210 B.C., found together when a cellar was dug in the city of Rhodes.[14] The jars are unlined, and there is no evidence for the stoppering.

Table 4. Capacities of Kleisimbrotidas–Theuphanes Jars

Number	*Range*	*Mean*
12	25.3–27.8	26.2
11	25.3–27.3	26.1 (26.05 rounded)
10	25.3–26.6	25.9

We notice again how close a single fabricant in a single year kept his dimensions, diameter within 1.1 cm. and depth and height within 1.7 cm. (Appendix 5).

These four groups, each containing substantial numbers of closely contemporary Rhodian amphoras, suggest, in summary, that mean total capacity of the jars *before* lining and stoppering was, say, 26–26¼ liters about 300 B.C. (the Kyrenia wreck), about 27¼ liters in

[12] A few millimeters' variation in maximum diameter or a slight change in profile that affects how high up on the jar the maximum diameter occurs may alter the capacity significantly; variations in depth also contribute; cf. Grace 1949, p. 176, "Measuring", note 12.

[13] We use "norm" here informally to designate the quarter-centimeter mark closest to the median value (the mid-point between the largest and the smallest measurement in the group); it is neither a mean (the average of all the measurements in the group) nor a "target" (by which we mean the dimensions aimed at by the potter, see below p. 293), although it may be close to each.

[14] The records of the Ephoreia give the findspot as Οἰκοδομή Παπαγεωργίου "λάκκος". On the date cf. footnote 7 above.

the 230's (Hôtel de Soleil deposit), just under 26¼ liters twenty years later (Kleisimbrotidas–Theuphanes group), and about 25½ liters *ca.* 200 B.C. (Villanova find). In addition whole jars are to be found singly or in small groups in museums and in excavation storerooms. Here one may take and compare not ten or twenty capacity measurements from the jars of a single year or even a single eponym-fabricant pair but a small sample of the production over a considerable period. In this paper we limit ourselves to discussion of the four large groups except to note that Virginia Grace's results indicate an increased mean capacity during the middle and later 2nd century B.C., perhaps roughly 27¼ liters gross or, say, 26½ liters after lining and stoppering.[15]

In the period between *ca.* 300 and *ca.* 100 B.C., then, the variation of individual jars and the fluctuations of the mean within the Rhodian amphora series are substantial to the point of being alarming, whether to a consumer at the time or to a scholar today. That a single amphora might have a gross capacity anywhere from 23 to 30 liters is in itself less serious than it may appear. As the primary use of wine amphoras in the major series, such as the Rhodian, was doubtless for bulk trade, and individual variations were unimportant provided that the jars in a sizable shipment aimed at a single "target" and were filled with some attempt at uniform fullness. Oversized and undersized specimens would compensate for one another, and a lot of even 10 or 20 amphoras would hold very closely what it should.[16]

[15] We exclude a group of 12 Rhodian amphoras, not all complete, reported by F. Benoît, *Gallia*, Suppl. XIV, *L'épave du Grand Congloué à Marseilles*, Paris 1961, p. 29, as having a capacity of 25 liters "en moyenne", since no figures for individual measurements or statements about method were published. The dating has also been somewhat unclear, as the wreck containing the Rhodian jars was at first not distinguished from a later one on the same site (see E. L. Will, "The Sestius Amphoras: a Reappraisal," *JFA* 6, 1979, pp. 339–350, esp. 339–341). In a forthcoming article on the building fill for the Middle Stoa in the Athenian Agora Virginia Grace will date the Rhodian material to the last decade of the 3rd century B.C., that is, between the Kleisimbrotidas group and Diskos' Villanova jars, when we should predict a mean capacity of between 26 and 25½ liters.

For the increase later cf. *Délos* XXVII, p. 298, "The capacity of the common Rhodian container, from a high of 28 to well over 29 liters in the middle to third quarter of the 2nd century B.C., seems to have fallen gradually to about 26 liters at the date of the [Antikythera] wreck; afterwards, in the second or third quarter of the 1st century B.C. it dropped to below 23 liters, and seems not to have gone above this figure in later times." (All figures are for gross capacity before lining and stoppering.) The data were of course obtained on many different occasions and with different equipment, and our own difficulties in comparing our results on the same jars in three successive years have underlined for us the dangers inherent in composite data (see Appendix 1). Only three of Virginia Grace's results were over 28¾ liters (one is cited in footnote 19 below). The 14 jars listed as over 28 liters (including these three) were measured in 1939 on Cyprus (except for two done in Istambul and recorded as holding 28.1 and 28.3 liters and one done at the Stoa of Attalos, but with grain, not water, and recorded as holding 28.8 liters; for the increased margin of error, see "Measuring", Appendix 3). Seven of eight measurements taken later at the Ringling Museum in Sarasota Springs, Florida, of jars of the second half of the 2nd century B.C. ranged from 26.0 to 27.9 liters (one jar was one cited by Dumont, *op. cit.* [footnote 3 above]), while the eighth was 25.0. It seems possible that the Cyprus results should be adjusted down; see V. R. Grace, "The Commercial Amphoras from the Antikythera Shipwreck," *TAPS* 55, 1965, pp. 5–17, p. 7, note 8: "The figures [for Cyprus measurements] are perhaps consistently a little high (I think allowance may not have been made for absorption [of water during measuring])." If we suppose that individual jars continued to have capacities that fell in a range from at least a liter below to at least a liter above the intended target, the raw data would put the highest likely target at roughly 27¾ liters, but we think it more likely that the actual figure was no greater than 27¼ liters, with a range from 26 or 26¼ to 28¼ or 28½ liters.

[16] The mean of the 13 unbroken jars of the year of Kratidas is 25,408 cc.; that of the 5 of the year of

Nevertheless a batch might hold on average anywhere from 24½ plus to 26½ liters of wine per jar, and these shifts clearly do require explanation. One reaction might be simply to question the evidence. When a large group of Rhodian transport amphoras is found unlined and unstoppered at home on Rhodes, clearly not in use for carrying wine, one wonders whether one is not perhaps dealing with a set of discards. There are actually aspects of both the Hôtel de Soleil and the Villanova groups that might support the theory that they were rejects, such as the presence of some unstamped, some older, and some apparently defective jars.[17] While it would be rash to insist upon the acceptability of every jar in both lots, it is worth emphasizing that the capacity range of the jars of Diskos (all but one within *ca.* 2 liters) is laudably low, in fact as low as that of Kleisimbrotidas. It is unlikely that so competent a pottery in fact turned out many dozens of jars seriously undersized. And to reject the Hôtel de Soleil jars (or even both the Hôtel de Soleil and the Villanova jars) would not remove the problem of the fluctuation of the mean capacity over time.

One might rather try to interpret the apparent fluctuations as official changes. Larger jars may have been designed to contain more units of the same standard or the same number of units on a larger standard. Neither possibility is easy to test. Virginia Grace pointed out long ago that there exist stamped Rhodian amphoras of one-half and one-sixth the normal size and unstamped lagynoi of one-twelfth. Recently I. B. Brashinsky has reported two more capacities each for jars of one-half and one-sixth the normal size and two for jars (apparently miniature amphoras rather than lagynoi) of one-twelfth and formally raised the question whether the sizes show that the normal jar held 12 Rhodian *choes*.[18] Perhaps the Villanova jars were intended to hold 11 *choes* of *ca.* 2¼ liters and the large jars that succeeded them 12 such "Rhodian" *choes*. This scheme might accommodate some of the Kyrenia outliers at 9 and 10 *choes* and a handful of apparently outsize jars at 13 *choes*.[19] One is,

Hieron is 25,320. Dr. David Smith tells us that statistical theory indicates a mean of between 25.1 and 25.7 liters for 19 out of any 20 batches of 10 jars made by Diskos in these two years; for 30-jar batches the mean will be between 25.2 and 25.6. Persons concerned with the wine trade in the period must have been aware empirically that the number of jars was a sufficient guide to the size of shipment, and it is so used both in papyri and in literature, cf. Grace, 1949, pp. 175–177 and "Measuring", note 3.

[17] For a warning that the Villanova lot may be factory discards see *Délos* XXVII, p. 294, note 1. Older jars are mentioned in footnote 9 above; unstamped Rhodian jars found in the Rhodes Museum by Virginia Grace in 1949 with Villanova jars and bearing inventory numbers close to theirs include VG R 53 and VG R 65; certain jars appeared to have suffered damage before being placed in their final location (old breaks, discoloration ending at cracks, and blackening were noted); one jar (VG R 87) had an eponym stamp on both handles. The Soleil deposit included one jar much older and smaller than the rest (A48 = ΜΣ 387, eponym Eukles), four unstamped jars (A43 = ΜΣ 374, A196 = ΜΣ 400, A220 = ΜΣ 342, A227 = ΜΣ 344), and a good many jars that were misstamped (i.e., with eponym stamps on both handles or with fabricant stamps on both). Moreover, the range of capacities was disquietingly large. See further discussion in Appendix 4; even a set of discards may have implications for the standard prevailing at the time of discard.

[18] Grace, 1949, p. 180; cf. *Délos* XXVII, p. 279 with note 2; Brashinsky, 1978, pp. 11–16, esp. 14–15. Note also Benoît, *op. cit.* (footnote 15 above), p. 29, reporting 16 Rhodian fractional jars of height 0.49, 6 of them complete with a (mean?) capacity (about?) 3.75 liters.

[19] The system postulated is (approximately): 9 *choes*, 20¼ liters; 10 *choes*, 22½ liters; 11 *choes*, 24¾ liters; 12 *choes*, 27 liters; 13 *choes*, 29¼ liters; each norm would have a tolerance of over a liter (cf. footnotes 15 and 21 below). Outsize jars are published in Grace, *op. cit.* (footnote 15 above), pp. 5–17, no. 8 (CMC 198, jar of Euphranos in the year of Nikasagoras II, capacity 30.0 liters, but see footnote 15

however, a little sceptical of a proliferation of poorly attested secondary denominations (especially in the same ship's cargo[20]). The target of the Kyrenia jars would have to be described as 11½ *choes* or the entire batch explained away, and the Kleisimbrotidas–Theuphanes jars would also be difficult to interpret. When the whole picture of Hellenistic Rhodian liquid-capacity standards as they affected wine amphoras is known, a change of denomination may appear, but such change does not plausibly account for all the fluctuation of capacity we have seen. Similarly, a change of standard during the period is entirely possible,[21] but while speculations can be multiplied there seems no plausible way of making changes of standard, even combined with changes of denomination, explain the whole series of norms.

A third interpretation might be that the jars were made only to some rough category of size and that their contents were normally measured into and out of them, or both, or that they were made to exceed a minimum capacity to which they were normally filled.[22] If, however, there was a single minimum or if the jars were made in a single rough category, the amount of fluctuation may be explainable, but there seems no explanation at all why only a part of the range between 23 and 30 liters was in use at any given time and why that part changed. Surely buyers and sellers and tax authorities would have been upset by such changes? One would at least expect to find a certain number of graffiti noting capacity on Rhodian jars if they were not regarded as achieving a known target within an accepted tolerance, and we know of only one instance.[23]

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above); Brashinsky, 1978, p. 14, no. 6 (capacity 30.4 liters); C. Muşeţeanu *et al.*, *Dacia* 22, 1978, p. 182, no. 32 (inv. no. 15105, jar of Hieroteles in the year of Timostratos, capacity 30.5 liters). Compare MΣ 462 in Table 10, jar of Hieroteles in the year of Ariston, capacity 32.2 liters.

[20] Michael Katzev tells us, for instance, that, among the Kyrenia jars that were not measurable by water but were sufficiently well preserved to measure for height and diameter, only one had dimensions close to those of the jar that held 20.4 liters, and we find it hard to explain why a cargo of hundreds of 26-liter jars should include a couple each of other denominations. We know of only one other Rhodian amphora that holds less than 23 liters (apart from obvious "fractionals"), A4, an unstamped jar of the late 4th or early 3rd century, capacity 20.7 liters.

[21] It is not clear whether a Greek state normally changed all its standards of length, weight, and capacity from one system to another at the same time or whether it was common for one standard to be changed alone; certainly coin standards, at least, were quite frequently changed and capacity standards may well have been (cf. "Measuring", notes 6–8). In the 4th century, Rhodian coinage was on the Chian standard (about eight ninths of the Attic), but Rhodian linear standards have been thought to have been similar to Attic or slightly greater (cf. recently J. R. McCredie *apud* D. Mitten *et al.*, *Studies Presented to George M. A. Hanfmann*, Cambridge, Mass. 1971, p. 99 with note 24). To give a single example of the metrological pitfalls that exist, in footnote 19 it was suggested that 9 *choes* on a hypothetical Rhodian system would be about 20¼ liters. But 6 Attic *choes* would be about 19.6 liters, 7 *choes* on the Chian system would be about 20.2 liters, and 4 *choes* on the Lakonian (Aiginetic?) system would be about 18.7 liters, and a 19½ liter jar might plausibly be taken to fit any one of these descriptions, or, no doubt, others.

[22] A suggestion of this sort about Knidian amphoras was made by M. Lang, "Numerical Notation on Greek Vases," *Hesperia* 25, 1956, p. 7 (discussion of no. 19); cf. *ibid.*, p. 4 with note 7. Roman oil jars were often weighed first empty and then full to measure their contents; see D. Colls *et al.* *L'épave Port-Vendres II*, *Archaeonautika* I, Paris 1977, pp. 83ff.

[23] Inv. no. 15107 in the archaeological museum of Calarasi, as reported by C. Muşeţeanu *et al.* (*op. cit.* [footnote 19 above], p. 181), eponym Polyk[les], fabricant Ona[sim]os (one of whose stamps from the late 2nd or early 1st century is cited in *Délos* XXVII, p. 197 with note 1); capacity 28.5 liters. The graffito is complex: on one side it runs ME IIIII H IIIIII H I, perhaps five measures (*μέ[τρα]*) and six

It is time to invoke our numismatic analogy (above, p. 294). Suppose a numismatist had ascertained that the norms of successive issues of a silver coin series were, say, 25.7 gm., 27.3 gm., 26.2 gm., 25.5 gm., and 27.3 gm. No great fuss would be made. One would suppose that the nominal full standard lay at or near the top of the range and that the fluctuation in actual standards was produced more or less unofficially in the operation of the mint: at its most respectable in answer to the fluctuating price of silver, at its least respectable as the result of downright theft or fraud. The analogy between weight of silver and space for wine is of course inexact; its essence lies in the tension between nominal and actual.[24] The following scenario is obviously imprecise and incomplete and may need serious revisions in the light of further evidence, but we hope that it may help in finding the right track.

The Rhodian state had then, we suppose, promulgated official standards of capacity. One convenient denomination was apparently somewhat over 26 liters net in our system (whether 1 Rhodian *metretes* or 8 Attic *choes* or 9 Chian *choes* or whatever it was in contemporary terms). With the Macedonian occupation of Egypt and the growth of the Rhodian bulk wine-export trade there and (to a smaller extent) elsewhere, the major producers of commercial amphoras came to make them, perhaps rather roughly at first, to that size. By 300 B.C. the practice of stamping Rhodian amphoras was beginning. In the Soleil lot we see the stamping extended to include mention not only of the pottery and the year but even of the month; at the same time the actual capacity norm appears to have risen somewhat to the point where the average jar could be lined and sealed and still really hold a good 26 liters plus of wine (perhaps a liter more than the average Kyrenia jar). Potteries over the next generation gradually reduced the maximum diameter by imperceptible amounts and gradually adjusted the profiles without official intervention;[25] the same height and depth as those in the Soleil lot, are 17 or 18 millimeters slimmer and hold over 1½ liters less. Almost all jars now hold within a liter of the norm (± 4%). At some point after Diskos, a reaction occurs, and capacities jump to roughly 27¼ liters (say 26½ liters lined and sealed); but all the increase was secured by making the jars taller, and we cannot know whether their imposing necks actually were filled as high as their predecessors'.

twelfths (ἡ[μίεκτα]) plus one half (ἥ[μισυ]). The occasion of the measuring and the absolute value of the units involved naturally remain obscure. We owe the restorations of the names to Virginia Grace.

[24] In two respects the analogy may actually tend to make the fluctuations seem less insignificant than they should. For visual convenience we have compared hypothetical coins of 25.7 gm., 27.3 gm., etc., to amphoras of gross capacity 25.7 liters, 27.3 liters, etc. But such coins would be exceptionally large, whereas Rhodian amphoras are of only middling size (not as much larger than Chian amphoras, for instance, as they are smaller than Koan amphoras, on the whole). A fairer comparison would use coin weights of 12.9, 13.7 gm., etc., and coin weights could be controlled within a smaller percentage of error than amphora capacities. A change of half a gram in coin weight is clearly more serious than a change of half a liter in amphora capacity, which is in fact, we suspect, slight enough to have been rather hard for ancient authorities to monitor, unless they developed the equivalent of volumetric flasks and tables of mean absorption during measurement and all the paraphernalia of Appendix 1.

[25] In an unpublished memorandum (May 20, 1954) Virginia Grace wrote of the jars of Aristos in the Villanova deposit that apparently (see footnote 9 above) "his jars were consistently more capacious than those of Diskos ... it may be that between the two there was a change in the regulations or in the strictness of their enforcement." It is the latter possibility that we elaborate here.

APPENDICES

All jars cited in the Appendices which are not listed in Appendix 2, Table 9 (Villanova jars with VG R numbers) or Appendix 5, Table 16 (Kleisimbrotidas–Theuphanes jars A22–A33, A88 [ΜΣ 467–ΜΣ 478]) are also Rhodian amphoras from between *ca.* 300 and *ca.* 100 B.C.

APPENDIX 1: Water Measurements of Rhodian Jars on Rhodes 1979–1981

All measurements were taken by filling the jars with water, waiting while some was absorbed by the clay, refilling to the brim, and siphoning the water out into containers of known size. Details of the method are given in "Measuring", under Method 2.

Error in the actual process of measuring may be estimated from the range of results of repeated measurements of the same jar (Table 5). In 8 sets of 3 such measurements listed in Table 5, and 5 sets of 2 (only one of which is shown here), the greatest discrepancy was 130 ml., the next greatest 87 ml. The mean of the ranges of the 8 sets with 3 results was 52 ml.

A second source of error is loss of water by absorption into the walls of the jar during emptying. Even after the initial period of soaking up mentioned above, the jar continues to take in water, although at a diminished rate. In general, one probably loses as much as 300 ml. to absorption in the process of emptying a very porous jar, soaked only 15 minutes and emptied in 15 minutes, but as little as 25 ml. with a less porous jar, soaked for 90 minutes and emptied in 10 minutes ("Measuring", Appendix 1). Our records about absorption do not all show the same time intervals. We list here (Table 6, p. 304), however, all the Kleisimbrotidas–Theuphanes and Diskos–Hieron/–Kratidas jars for which we have a trustworthy figure for absorption at the end of one hour.

Note that where a figure for the first half hour is recorded it is over three-quarters of the total for the hour (and so the rate clearly slows down sharply) and that the two batches differ systematically. We may very roughly estimate that such jars, measured after an hour's soaking up, absorb less than 75 ml. during the 10 to 15 minutes of measuring. Our net figures (after allowances for lining and stoppering) are therefore all up to 75 ml. low; we have made no allowances for absorption in any of our results.

To our surprise, however, the most serious error arises in establishing the sizes of the containers used in measuring. The average of 3 measurements in 1979 for VG R 24, for example, was one demijohn less 85 ml. We measured the demijohn by siphoning its contents 4 times into a bottle (capacity 2055 ml. from 5 measurements taken to the brim with a 250 ml. graduated cylinder), obtaining a capacity of 12 bottles less 20 ml., or 24,630 ml. to an accuracy of ± 0.2%, so that the jar's capacity should be 24,545 ± 50 ml.[26] The average of 3 measurements in 1981 for the same jar was

[26] The accuracy depends on the measurements of the bottle and the demijohn. The five measurements of the 1979 bottle gave 2,052, 2,056, 2,056, 2,056, 2,058 ml., averaging 2,055.6 ml. (a sixth measurement, taken later, gave 2,062 and was discarded as too high; one might have discarded the lowest, 2,052, instead and taken the mean value as 2,057). Four measurements of the 1979 demijohn ranged from 12 bottles − 20 ml. to 12 bottles − 39 ml.; the first result, 12 bottles − 125 ml., was therefore discarded. One measurement by filling came exceedingly close to 12 bottles but, given a slight spill, was counted as a third result

Table 5. Triple Measurements with the Same Containers[27]

Inv. No.	*1979*	*1980*	*1981*
VG R 22	1 Dj. + 1 B − 882		
	1 Dj. + 1 B − 840		
	1 Dj. + 1 B − 830		
Range	52		
VG R 24	1 Dj. − 88		1 Dj. − 1 B + 622
	1 Dj. − 103		1 Dj. − 1 B + 590
	1 Dj. − 62		1 Dj. − 1 B + 648
Range	41		58
VG R 33	1 Dj. − 82		
	1 Dj. − 36		
	1 Dj. − 40		
Range	46		
A32 (ΜΣ 476)		1 Dj. + 578	1 Dj. + 537
		1 Dj. + 517	1 Dj. + 500
		1 Dj. + 545	1 Dj. + 538
Range		61	38
ΜΣ 637		1 Dj. − 250	1 Dj. − 1 B + 57
		1 Dj. − 214	1 Dj. − 1 B + 187
		1 Dj. − 230	
Range		36	130
A129 (ΜΣ 484)			1 Dj. + 1 B + 30
			1 Dj. + 1 B + 112
			1 Dj. + 1 B + 115
Range			85

one demijohn less 380 ml. The 1981 demijohn was siphoned 3 times into a 1-liter cylinder, with a result of 25 cylinders plus 320 ml., so that the jar's capacity should be 24,940 ± 50 ml. The discrepancy is 395 ml. Three 1980 measurements average 190 ml. greater than 1979 measurements for the same jars (A32, A126, and A129); five 1981 measurements averaged 415 ml. greater than the 1979 measurements for the same jars (those just listed, and VG R 23 and VG R 24); and five 1981 measurements averaged 270 ml. greater than the 1980 measurements for the same jars (Table 7). Given the low standard deviations (Table 7c), which show good repeatability for the methods used in all three years, these discrepancies are clearly significant: either the capacity of the same jar,

of 12 bottles − 20 ml. and, averaged with the four sound results by emptying, gave 24,629.2 ml., rounded to 24,630 ml. If the bottle was counted as 2,057 ml. and the demijohn as 12 bottles − 20 ml., the demijohn would become 24,664 ml., doubtless rounded to 24,665. Associated with this slight imprecision in determining the sizes of our standard containers is a slight variation in the precise point in the graduated cylinder that a given worker on the average takes as "to the line". An inaccuracy estimate of ± 0.2% seems warranted.

[27] Dj. is "Demijohn" and B "second container" (small bottle or cylinder). Demijohns and second containers were different in different years. Figures with no indication of containers are in ml. E.g., VG R 22 was measured the first time as 1 demijohn, plus 1 bottle less 882 ml., i.e. 882 ml. were required in addition to the contents of the amphora to fill 1 demijohn plus 1 bottle.

Table 6. Amounts Soaked up before Measuring

Inv. No.	*After 30 mins. (ml.)*	*After 1 hr. (ml.)*	*Ratio*
A26 (ΜΣ 477)		735	—
A27 (ΜΣ 478)		515	—
A29 (ΜΣ 467)	678	826	82%
A33 (ΜΣ 471)	602	788	76%
VG R 20	730	916	80%
VG R 21	500		—
VG R 25	908	1101	83%
VG R 90	490	628	78%

measured in successive years, is actually greater one year than it was the year before or the absolute values of the capacity measurements vary through error in calibration of the equipment.

We doubt that the jars are currently growing at a rate of roughly 1% per annum.[28] The now obvious source of discrepancy lies in the margin of error of glass graduated cylinders. Two 250 ml. cylinders at the Stoa of Attalos in March, 1982 were marked " ± 2 cc at 20° C", and we understand from Dr. D. F. Matheson that larger cylinders in general also vary often by at least ± 1%. The one-liter cylinder used in 1981 was checked against a volumetric flask at the Stoa on the advice of Stephen Koob, Agora Conservator, and showed (unlike its rejected counterparts) no perceptible divergence. Accordingly we believe that the 1981 results are as close to accurately calibrated as it is easy to come.[29] Nevertheless, in 1981 we checked five jars by weighing them full (after soaking) and

[28] That is not to say that one should expect the jar to exhibit exactly the same capacity within the limits of error whenever and however often one measures it. For example, in the 13 cases of remeasurement with the same equipment mentioned above (p. 302), 10 of the second measurements were greater than the first measurements, and the mean of the 13 second measurements was 31 ml. greater than the mean of the corresponding first measurements. (The mean of the 8 third measurements was 6 ml. higher than the mean of the corresponding second measurements, which is not clearly significant.) This small effect may be illusory or accidental but may be caused by a lower rate of absorption in jars that were soaked up a second time within a short period. More significant, even though we shake out loose dirt before measuring, it is likely that the water weakens the adhesion of what dirt remains even after measuring so that when we return in a subsequent year and dump the jar before starting to measure, some of what was counted as interior wall in the last measurement is dislodged. In the case of jars whose surface is slowly being flaked off by salt action we may in fact lose a little even of the original clay. But a "dumping factor" should affect some jars more than others, and Table 7 shows a fairly uniform effect on all seven jars (2 Villanova, 2 Kleisimbrotidas, and 3 miscellaneous) that were measured in different years.

[29] Of course even the volumetric flask, let alone the cylinder validated from it, is not immune from error. For example the flask was weighed full and empty on accurate scales at the Stoa of Attalos on March 6, 1982 and the weight of the contents determined as 996.45 gm. One liter of water at 15°C weighs 999.13 gm. (*CRC Handbook of Chemistry and Physics*, R. C. Weast, ed., 62nd ed., 1981/1982, Boca Raton, Florida 1981, p. 114). The flask was weighed empty later and the weight recorded at 1.0 gm. less than the previous empty weight, most of the difference being attributable to the evaporation of the last particles of water clinging to the interior walls from the initial filling. The implication is that the true contents was 997.45 gm. Distilled water, free from air, was not used, and the temperature may have been somewhat (although not much) above 15°C. It would not be unreasonable to suppose that if distilled water at 15°C, free from air, had been used, and if every particle of water had been emptied out, the scales would have recorded a difference of about 998 gm. and been in error by about 1 gm. or 0.1%, vindicating the flask completely. But it cannot be firmly denied that the calibration of the flask could be up to 1 ml. out, and that the use of it to determine the capacity of the chosen cylinder introduced a further 1

Table 7. Multiple Results from Different Years and Methods[30]

Inv. No.	*1979*	*1980*	*1981*	*1981–Weight*
(a) Capacities				
A27 (ΜΣ 478)	—	24,927	25,343	24.95
				24.88
A32 (ΜΣ 476)	25,260	25,426	25,857	25.44
		25,454	25,820	
		25,487	25,858	
A126 (ΜΣ 566)	27,870	28,120	28,275	—
			28,280	
A129 (ΜΣ 484)	26,063	26,183	26,435	—
			26,432	
ΜΣ637	—	24,175	24,377	24.14
		24,211	24,507	24.06
		24,195		24.02
VG R 23	25,308	—	25,660	—
			25,685	
VG R 24	24,542	—	24,942	24.55
	24,527		24,910	24.44
	24,568		24,968	24.55
VG R 72	—	—	23,985	23.56
(b) Soaking Data for above results				
A27	—	515 after 1	NA	NA
A32	798 at 1	1,075 at 4⅔	NA	NA
A126	1,640 at 1 1/12	1,475 at 1½	1,888 at 3½	—
A129	570 at 1⅓	484 at 1⅓	790 at 3¾	—
ΜΣ 637	—	?	NA	NA
VG R 23	1,294 at 2	—	655 at 1	—
VG R 24	1,282 at 2	—	NA	NA
VG R 72	—	—	NA	NA
(c) Mean ± Standard Deviations of Triple Volume Measurements				
A32	—	25,456 ± 30.6	25,845 ± 21.7	
ΜΣ 637	—	24,194 ± 18.1	—	
VG R 24	24,546 ± 16.9	—	24,940 ± 29.1	

ml. of error through incomplete emptying. It is not that we regard our calibration of the cylinder used in 1981 as perfect, simply that it is best to express all our results in a form comparable with the best-calibrated set.

[30] Volumes are given as calculated on each occasion, without rounding, to the nearest milliliter, weights to the nearest 10 grams, using the then current calibration. A dash means that the jar was not measured for whatever reason and NA that soaking data are not available (usually because the jar had already been soaked for a measurement a short time before). Soaking times are given in hours.

empty, and then taking the difference.[31] If one compares the weights of water contained with the volumes, equating 1,000 ml. with 1 kilo in Table 5, there is an obvious discrepancy of about 400 ml. or 400 gm. (actually, after all the averaging, 414 ml. or gm.), but then water at 15°C only actually weighs *ca.* 999 gm. per liter so that the true mean discrepancy is *ca.* 390. At the same time the *relative* values of the 1981 volume and weight results correspond very well (the discrepancies range from 385 for A32 to 435 for ΜΣ 637). Obviously there is a calibration error, and since the cylinder had been checked but the scales not, we conclude that (almost all) the error was in the scales. For purposes of comparison, therefore, we have added 400 gm. to 1981 water weights, 250 ml. to 1980 water volumes, and 400 ml. to 1979 water volumes.

The reader will share our awareness that the resulting figures are only approximately comparable. While the situation is somewhat improved by our having repeated measurements for several jars, it seems unreasonable in view of the three sources of error discussed above to give figures for individual jars more closely than to the nearest 50 ml. or to put confidence in them even to the nearest 100 ml. The mean of a group of jars is obviously much more reliable, and when, for example, we give the mean of Diskos' Villanova jars as 25.5 liters and the mean of the Kleisimbrotidas–Theuphanes jars as 26.2 liters, the difference of these means is reliably 0.7 liters to the nearest 100 ml. For interpretative purposes this is at least as much accuracy as we can use; indeed we doubt whether metrologists and economic historians should or would formulate theories incorporating results more precise than to the quarter liter (250 ml. is close to 1% of the volume of Rhodian jars and also about 1 *kotyle*, the smallest common Greek volumetric unit, in the Attic and the Chian systems). If what we are interested in is the effective capacity of the jars in trade, the uncertainties introduced by lining and stoppering procedures (which may well have changed from time to time) impose at least that much imprecision.

APPENDIX 2: WATER MEASUREMENTS OF VILLANOVA JARS 1949

Virginia Grace measured 50 jars from the Villanova find in 1949, and it is on these measurements that the bulk of our calculations about the mean capacity of the Diskos jars is based. We returned with her to Rhodes and remeasured 10 jars in 1979 and 1980; P. M. Wallace Matheson remeasured some of these and an 11th in 1981. Appendix 1 discusses the problems of comparing figures from the three years 1979–1981. It remains to establish a basis of comparability for the 1949 figures.

It will be seen from Table 8 that the *relative* capacities of the jars measured both in 1949 and in 1979–1981 agree quite closely but that our later measurements were consistently higher than the earlier ones by about 1.3 liters.[32] We have therefore added a supplement of this amount to all 50

[31] Details of the method are given in "Measuring". The ranges of repeated weight results were 70 gm., 120 gm., and 110 gm.

[32] Virginia Grace has kindly put at our disposal records of the techniques used in 1949, and we note the following possible differences: 1) the shape and size of the containers used (in 1949, two wide-mouthed containers with capacities of about 19 and 7 liters); 2) the fact that the 1949 results were calculated on the *minimum* calibrated values (a second measurement of the smaller container gave a higher value, which, if used in place of the first, would probably raise the capacity results of all the jars by about 0.4 liters); 3) the calibration of the graduated cylinder used (cf. Appendix 1, p. 304); 4) loss of water to absorption (different soaking-up times and different lengths of time taken in measuring) and loss through the *number* of containers filled and emptied in each measurement, and hence potential spillage (often as many as 7 to 8 containerfuls in 1949).

Table 8. Comparison of 1949 and 1979–1981 adjusted results

Inv. No.	*1949 (minimum)*	*1979–1981*	*Rounded to*	*Difference*
VG R 20	(22,300) + 1,280 =	(24,244)		
	[23,580]	(24,331)		
		Average (24,288) + 300 =		
		[24,588] + 250 = [24,838]	24,840	1,260
VG R 21	24,000	25,004 + 250 = 25,254	25,250	1,250
VG R 22	24,800	‡25,745		
		25,834		
		25,845		
		25,855		
		Average 25,845 + 400 = 26,245	26,250	1,450
*VG R 23	24,250	25,684	25,680	1,430
*VG R 24	23,650	24,928	24,930	1,280
VG R 25	24,050	25,091 + 250 = 25,341	25,340	1,290
VG R 32	(23,100) + 225 =	(24,107) + 255 =		
	[23,325]	[24,362] + 250 = [24,612]	24,610	1,285
VG R 33	23,600	24,548		
		24,590		
		24,594		
		Average 24,577 + 250 = 24,827	24,830	1,230
VG R 56	(25,400) + 970 =	(26,416) + 970 =		
	[26,370]	[27,386] + 250 = [27,636]	27,640	1,270
*VG R 72	(22,200) + 630 =	23,987	23,990	1,160
	[22,830]			
VG R 90	25,250	26,273		
		26,328		
		Average 26,300 + 250 = 26,550	26,550	1,300

All figures are given in milliliters.

All figures in parentheses are measurements which could not be taken to the rim of the jar (see footnote 8 above); they are followed by an estimated supplement for the neck, and the total estimated capacity is given in square brackets. VG R 20 and VG R 72 had been strengthened (the neck mended in plaster), and so did not require less (VG R 20) or no (VG R 72) estimated supplement in later years.

For multiple 1979–1981 results, we have first averaged the actual figures obtained, then added a further "neck supplement" where applicable, and finally added a further adjustment factor (400 ml. for 1979 results, 250 ml. for 1980 results, and 400 ml. [gm.] for 1981 weight results) to make all results comparable with the 1981 water-volume results (for explanation and details of this procedure see Appendix 1).

* Details of individual measurements for jars marked with an asterisk (*) have already been given, without adjustment, in Table 7; only the mean, calculated with the same adjustments as for the other figures in this table, is given here.

‡ Not included in the mean.

1949 measurements to produce 1949 adjusted results for use in calculations of the mean capacity of the Diskos jars.

If we find ourselves in the position of treating our results as more accurate in absolute value, we nonetheless owe the principal improvement (the use of the demijohn in place of wide-mouthed containers) to Virginia Grace's good advice, and we regard the agreement of our relative values with hers as a welcome indication that the reliability of our methods in the field approaches hers. A list of capacities of Villanova Rhodian amphoras as found by water measurement follows in Table 9. Where only one figure appears it is the 1949 result adjusted upward 1,300 ml. and rounded to 50 ml. Where two figures appear, the first is the adjusted 1949 result and the second is the mean of all 1949 and 1979–1981 results (for which see Table 8 above) after all adjustments, rounded to 50 ml.

Table 9. Capacities of Villanova Jars

Inv. No.	*Capacity*	*H*	*Depth*	*Dmax*
a. Diskos–Kratidas				
VG R 3	25,450	0.791	—	0.350
VG R 6	25,050	0.780	—	0.354
VG R 9	24,800	0.785	0.712	0.345
VG R 11	25,250	0.780	—	0.345
VG R 15	25,000	0.790	—	0.342
VG R 17	25,900	0.785	—	0.350
VG R 18	25,250	0.772	—	0.350
VG R 20	(23,600) + 1,280	0.766	0.712	0.347
	[24,880]			
Estimate	[24,850]			
VG R 22	26,100	0.783	0.728	0.356
Estimate	26,200			
VG R 23	25,550	0.777	0.713	0.351
Estimate	25,650			
VG R 24	24,950	0.774	0.726	0.349
Estimate	24,900			
VG R 26	25,650	0.780	0.718	0.355
VG R 27	25,250	0.790	—	0.350
VG R 28	(25,300) + 350	0.792	0.732	0.348
	[25,650]			
VG R 31	(24,600) + 140	0.770	0.705	0.346
	[24,750]			
VG R 32	(24,400) + 225	0.783	0.726	0.347
	[24,625]			
Estimate	[24,600]			
VG R 35	(26,400) + 240	0.784	—	0.352
	[26,650]			
VG R 59	(24,900) + 1,000	0.782	—	0.352
	[25,900]			
VG R 64	25,950	0.770	0.710	0.351

Inv. No.	*Capacity*		*H*	*Depth*	*Dmax*
b. Diskos–Hieron					
VG R 10	25,050		0.770	—	0.345
VG R 19	24,850		0.765	—	0.340
VG R 21	25,300		0.768	0.707	0.347
Estimate	25,300				
VG R 29	(26,250) +	350	0.776	0.721	0.345
	[26,600]				
VG R 33	24,900		0.770	0.712	0.345
Estimate	24,850				
VG R 48	(25,400) +	690	0.780	—	0.350
	[26,100]				
VG R 63	(24,350) +	710	(0.777)	—	0.346
	[25,050]				
VG R 71	(24,600) +	350	(0.765)	—	0.341
	[24,950]				
VG R 72	(23,500) +	630	0.772	—	0.336
	[24,150]				
Estimate	24,050				
VG R 90	26,550		0.779	0.752	0.351
Estimate	26,550				
VG R 92	(24,650) +	970	0.775	—	0.345
	[25,600]				
c. Diskos–Xenophanes					
VG R 7	24,450		(0.734)	—	0.35
VG R 8	26,650		0.76	—	0.35
VG R 14	26,500		0.77	—	0.36
VG R 16	26,500		0.775	—	0.35
VG R 54	24,750		0.78	0.712	0.349
VG R 76	(25,250) +	490	0.774	—	0.356
	[25,750]				
d. Diskos–Pratophanes					
VG R 25	25,350		0.772	0.718	0.355
Estimate	25,350				
VG R 30	(25,600) +	280	0.785	—	0.35
	[25,900]				
VG R 60	(24,850) +	600	0.787	—	0.351
	[25,450]				

Inv. No.	*Capacity*	*H*	*Depth*	*Dmax*
e. OTHER				
ISTROS–Kratidas				
VG R 85	(24,000) + 780 [24,800]	0.76	—	0.346
ISTROS–Pratophanes				
VG R 1	26,150	(0.732)	—	0.356
DAMOKRATES–Pratophanes				
VG R 2	24,250	0.79	—	0.34
ARISTOS–Archokrates				
VG R 82	(26,100) + 830 [26,950]	(0.732)	—	0.352
ARISTOS–Timasagoras				
VG R 56	(26,700) + 970 [27,650]	0.805	—	0.355
Estimate	[27,650]			
EPIGONOS–Simylinos				
VG R 46	(26,050) + 1,320 [27,350]	(0.745)	—	0.362
AGORANAX–*****				
VG R 66	(24,700) + 660 [25,350]	(0.732)	—	0.352
NIKAGIS–*****				
VG R 51	(25,100) + 535 [25,650]	(0.75)	—	—
*****–Hieron				
VG R 78	(25,450) + 870 [26,300]	0.78	—	0.348
*****–Kratidas				
VG R 74	24,650	0.72	—	0.344
*****–*****				
VG R 58	(24,700) + 695 [25,400]	0.772	—	0.347

APPENDIX 3: Polystyrene Measurements of Rhodian Jars on Rhodes 1979–1981

The basic form of measurement was filling a metal cup (which holds approximately a half liter) level full with small, uniform polystyrene pellets and emptying it into the jar as many times as needed to fill the jar level full[33] (any residue in the last cup was measured in a graduated cylinder). Details are given in "Measuring", under Method 3.

Error in the actual process of measuring may be estimated from the range of results of repeated measurements of the same jar by the same measurer in the same year (Table 10). The mean of the 12 ranges is 162 ml. (without A69, 103 ml.). This compares with a mean range of 275 ml. in 11 miscellaneous jars measured three times each with polystyrene pellets ("Measuring", under Reliability for Method 3).

In 1979 many measurements were taken by pouring a jar already filled, by cupful, with a known amount of polystyrene into a larger jar and making up the difference with cupfuls, or into a smaller jar and measuring the residue in the cylinder. The newly measured jar was used to measure a third, the third a fourth, the fourth a fifth, and then the process was restarted with a measurement by cupfuls. Nine jars were measured both by cupfuls and by pouring, and the "poured" results came out an average of about ⅓ liter higher than the results "by cup" (Table 11). The poured figure (with its high difference) for A177 was the result of only three pourings in a row, although that for A210 came from eight pourings and might well show a greater difference than the rest. We have no explanation for the low figure of VG R 24. The six instances where the poured figure is about 300 ml. higher are probably the typical ones.

[33] We considered also three indirect ways of estimating the capacities of broken and mended jars. I. B. Brashinsky in the paper cited above (footnote 1) boldly applies one of Heron's formulas for finding the volume of an amphora from its linear dimensions to three Rhodian jars of the early to middle 3rd century. He infers from their maximum diameter, exterior diameter of mouth with rim, and internal height (depth) as reported in millimeters, their probable intended or "target" dimensions in Attic dactyls, and substituting these values in the equation

Volume = 11/14 × average of maximum and minimum diameters squared × depth,

notes that the result is within *ca.* 2% of eight Attic *choes.* The three jars, however, are stouter and squatter than any in our four groups, and Brashinsky points out that the formula in question fails to work for Rhodian jars of the late 3rd and 2nd centuries.

Obviously, Heron's three formulas will apply at best to only a small fraction of Hellenistic amphora shapes; indeed, a given shape may have been selected empirically, without a capacity formula. Even with dimensions for almost 200 Rhodian jars from *ca.* 240–200 B.C. that probably shared a single official capacity standard we have not found a good hypothesis (whether in Attic or other terms) that states a set of official linear dimensions and a capacity formula based on them. Others may. Nevertheless, the official formula, if any, must conceal, rather than reveal, the minor fluctuations in actual mean capacity from decade to decade that it is part of our purpose to document.

Second, colleagues suggest that an experienced craftsman in an established factory would take or be issued a relatively uniform amount of clay for each amphora, so that once we know the capacity of a few specimens we may assign others of the same pattern to the same standard simply by weighing them empty. Empty weight, however, seems in practice to vary more than total capacity and not directly with it; for example, of the four unencrusted jars measured from the Kyrenia wreck (p. 296 above) the capacities ranged from 24.74 to 26.79 liters (*ca.* 8%) and the weights from 14.07 to 15.75 kilos (*ca.* 12%): the heaviest amphora held the least.

Last, work on calculating capacities from profile drawings by use of a plenimeter and a computer has been undertaken by Carolyn Koehler and David Seamans, and a similar project for smaller shapes by Daniel Pullen, but results are not yet available.

Table 10. Repeated Measurements in the Same Year[34]

Inv. No.	*1979*	*1980*	*1981*
VG R 22	50 cups − 50		
	50 cups + 30		
	(51 cups − 460 =)[35]		
	50 cups + 65		
Range	115		
VG R 23	50 cups − 435		49 cups − 45
	50 cups − 480		49 cups
Range	45		45
VG R 24	48 cups − 250		48 cups − 60
	48 cups − 150		48 cups − 275
Range	100		215
VG R 33	48 cups − 25		
	48 cups − 110		
Range	85		
A69 = MΣ 429	54 cups − 65		
	53 cups − 360		
	53 cups − 350		
Range	810[36]		
A25 = MΣ 472		54 cups − 435	
		53 cups	
Range		90	
A169 = MΣ 378		56 cups − 175	
		56 cups − 155	
Range		20	
A183 = MΣ 333		56 cups − 125	
		57 cups − 470	
Range		180	
MΣ 462		62 cups − 365	
		62 cups − 340	
Range		25	
MΣ 637		47 cups − 315	
		47 cups − 225	
		47 cups − 450	
Range		225	

[34] In all years the same metal cup was used, but the graduated cylinders into which the residue was measured in ml. differed, as did the measurer. This residue (given here as + or − the total number of cups) and the range of variation over each set of measurements are given in milliliters.

[35] The value to be used for the cup depends on the calculations in Table 14; 525 ml. is a rounded mean of values from about 519 to about 528 ml.

[36] While the previous four jars were remeasured on purpose by the same measurer on the same day, this jar was accidentally remeasured (because of a confusion over the inventory number) four days after the first measurement, still by the same measurer. When this was discovered the discrepancy of 810 ml. prompted the third measurement (four days later again, still by the same measurer). It seems likely that the jar was inadvertently tapped or shaken during the first measuring, so that the pellets settled down more densely into it (cf. below p. 314), and for any purpose except the present one we should simply ignore the "wild" figure.

Table 11. Polystyrene Measurements by Pouring and by Cup, 1979[37]

Inv. No.	*Poured*	*By Cups*	*Difference*
A35 (ΜΣ 389)	54 cups – 1,775 = 51 cups – 200	51 cups – 455	255
A92 (ΜΣ 404)	54 cups – 2,250 50 cups – 150	50 cups – 425	275
A177 (ΜΣ 367)	60 cups – 2,355 = 55 cups + 270	55 cups – 280	550
A186 (ΜΣ 332)	63 cups – 5,510 = 52 cups + 265	52 cups – 85	350
A198 (ΜΣ 405)	58 cups – 2,350 = 53 cups + 275	53 cups – 40	315
A200 (ΜΣ 407)	60 cups – 4,930 = 51 cups – 205	51 cups – 480	275
A210 (ΜΣ 346)	63 cups – 5,175 = 53 cups – 75	52 cups – 20	470
ΜΣ 554	54 cups – 2,510 = 49 cups + 115	49 cups – 185	300
VG R 24	50 cups – 1,075 = 48 cups – 25 and 48 cups – 250 Average 48 cups – 140	48 cups – 200	60

These nine repetitions were undertaken at random; in 1981 we had nine further remeasurements, made by cupful, of jars for which the poured result seemed rather high or rather low for the eponym-fabricant pair in question (Table 12); in five cases we have also 1980 measurements by cupful. The notably wide variation in the right-hand column, which shows poured measurements ranging from 1150 ml. greater to 740 ml. less than measurements by cupful, is partially misleading for two reasons. The jars selected in 1981 were precisely those where the poured result was most suspicious; the case of A65, for example, does not show that proper poured measurements may sometimes be lower than measurements by cupful but that we were right to doubt so low a figure as 53 cups – 455 (our lowest result) for a jar of Xenotimos in the year of Pausanias (Soleil group). Something had evidently gone wrong with the poured measurement. Second, the 1981 results were all obtained by R. Angelinakes, and there are likely to be slight systematic differences between the results of different measurers and even of the same measurer in different years.

In 1980 D. Mouliates redid by cupful 10 jars he had done in 1979 (9 of them by pouring; the other is marked "cupfuls" in Table 13). Mouliates 1980 result by cupful agrees reasonably well with 1979 poured results (and the 1979 cupful result is somewhat lower, as we should expect from Table 11). The poured results are systematically higher than Mouliates 1979 results by cupfuls. Thus the 1980 results by cupful are systematically higher than the 1979 results by cupful.

Returning to Table 12 we see that Angelinakes 1981 results tend to fall somewhat below the 1979 poured results, although not perhaps by as much as Mouliates 1979 results, and above a variety of results by cupful[38] (as also with his two remaining remeasurements, of A64 (ΜΣ 424)

[37] Residue and difference are given in milliliters; the cup is reckoned at 525 ml. Cf. footnotes 34 and 35 above.

[38] Also, the 1981 results are 205 and 315 greater for A25 and A169, where the 1980 results were sus-

Table 12. Remeasurements by Cupful of Jars Measured by Pouring, 1981[39]

Inv. No.	*1981*	*1980*	*1979 Poured*	*Difference 1981–1979*
A25 (ΜΣ 472)	54 C − 275	54 C − 435 (P) 53 C exact (P)	56 C − 1100 = 54 C − 50	+ 225
A34 (ΜΣ 443)	50 C − 245		52 C − 1234 = 50 C − 195	+ 50
A65 (ΜΣ 432)	54 C − 240		59 C − 3605 = 53 C − 455	− (1 C + 215) = − 740
A70 (ΜΣ 447)	56 C − 180	55 C − 425 (Z)	57 C − 425	1 C − 245 = + 280
A164 (ΜΣ 355)	49 C − 220	48 C − 50 (M)	51 C − 1595 = 48 C − 20	− (1 C − 200) = − 325
A169 (ΜΣ 378)	57 C − 385	56 C − 175 (Z)	59 C − 545 = 58 C − 20	1 C + 365 = + 890
A183 (ΜΣ 333)	58 C − 270	56 C − 125 (Z) 57 C − 470 (Z)	70 C − 5870 = 59 C − 95	1 C + 175 = + 700
A194 (ΜΣ 421)	54 C		57 C − 425	2 C + 100 = + 1150
A224 (ΜΣ 341)	51 C − 320		58 C − 3870 = 51 C − 195	+ 125

[57 cups − 480] as opposed to Mouliates 1979 [56 cups − 295] and of A173 (ΜΣ 322) [49 cups − 200] as opposed to Zimmerman 1980 [49 cups − 415]). We do not have the data for a statistical analysis. But it does not seem unfair to say that the poured results do not appear from Tables 11–13 to achieve repeatability within the same limits that Table 10 shows for results by cupful obtained by the same operator on the same occasion.

It is obvious, in addition, that we must use single polystyrene results with caution. Adding the measuring error of Table 10 to the systematic error in combining measurements taken on different occasions, we find that even a single result by cupfuls may mislead one by half a liter and occasionally more. The remedy, obviously, is to concentrate on groups of jars, the larger the better, and to try to control the amount of error by remeasurements on several occasions.

It remains to use the polystyrene results to find actual capacities. As is explained in "Measuring", under Method 3, polystyrene pellets differ from water in that a given quantity does not occupy a constant volume (the pellets would tend to pack more tightly toward the bottom of a jar, for example) and in that the pellets do not occupy the whole of the jar fully. In 1980 we patched one jar that had a piece missing from its shoulder with clear tape, at Claire Zimmerman's suggestion, and were able to see how air space was left at the shoulder even when the pellets had come up to the top of the

pected of being too high, and 355 and 215 greater for A164 and 173, where the 1980 results were thought low, from which it seems likeliest that the 1980 results for these four jars were not, after all, distorted and that Angelinakes 1981 results are systematically higher.

[39] For A25, A70 and A183 part of the neck had to be simulated each time with plasticine and for A164 and A169 with cardboard, which obviously increases the likelihood of divergent measurements in different years. C = cup, P = P. M. Wallace Matheson, Z = Claire Zimmerman, M = Demetrios Mouliates. All 1981 measurements were by Roussos Angelinakes. Residue and difference are given in milliliters; the cup is reckoned at 525 ml.

Table 13. Mouliates Results in 1980 and 1979[40]

Inv. No.	*1980*	*1979*	*Difference*
A30	49C	52C − 1755 = 49C − 180	+ 180
A48 (ΜΣ 387)	46C − 405	45C (cupfuls)	+ 120
A50 (ΜΣ 385)	55C − 130	56C − 505	− 150
A138 (ΜΣ 548)	52C − 420	57C − 3020 = 52C − 395	− 35
A164 (ΜΣ 355)	48C − 50	51C − 1595 = 48C − 20	− 30
A178 (ΜΣ 365)	56C − 465	56C − 460	− 5
A206 (ΜΣ 397)	58C − 300	60C − 1205 = 58C − 155	− 145
ΜΣ 462	62C − 365 62C − 340	65C − 1895 = 62C − 320	− *ca.* 30
ΜΣ 504	51C − 485	56C − 3095 = 51C − 470	− 15
ΜΣ 549	47C − 190	51C − 2410 = 47C − 310	+ 120

neck. For these two reasons polystyrene measurements do not themselves directly give true capacities. One has to measure several jars repeatedly both with water and with polystyrene and equate the average of the water results to the average of the polystyrene results. Then one may infer the approximate "equivalent value" of a cup of polystyrene pellets (for jars of this shape and size).[41] Table 14 sets out our calculations. The seven "equivalent values" have a mean of 523.2 and a range of 8.7. The first four sets of polystyrene figures are Mouliates 1979, the fifth Zimmerman 1980, the sixth and seventh those of two other measurers in 1981. While Table 12 may suggest systematic differences among the three sets of figures, we note that the 1981 figure for VG R 24 was only about 30 ml.

[40] Residue and difference are given in milliliters; the cup (C) is reckoned at 525 ml.

[41] We know that the use of a "mean equivalent cup" seems like an unnatural, over-theoretical approach to the problem of comparing polystyrene and water results.

It is possible to do the same calculations without invoking the "equivalent cup", using spotchecks on the amount of polystyrene contained in the actual cups used during each measurement. This was done for VG R 23 and VG R 24 in 1981. The measurer of VG R 23 (Mikhales Kostas) proved through 3 spotchecks to use an average cup of 519 cc., while David Jordan, measuring VG R 24, had an average cup of 507 cc. This produces the following "direct result" calculation of an adjustment factor for polystyrene measurements:

	VG R 23	VG R 24
Mean result:	49 cups − 25	48 cups − 170
Mean cup value:	519	507
Capacity (polystyrene):	25,406	24,166
True (water) capacity:	25,650	24,900
Discrepancy:	244	734
Discrepancy (as a percentage of mean polystyrene result):	0.96	3.04

It will be seen from this that, as with the "equivalent cup" method, measurements from many jars will be needed to establish a mean percentage discrepancy which can be used to convert polystyrene measurements to their true (water) equivalents and that the "direct result" method requires data on multiple spotchecks for every jar. The "equivalent cup" method expresses the same discrepancy (caused by the packing of the polystyrene and the difficulty of filling the shoulder completely, see p. 314 above), using the same total number of actual cups for each individual jar. The differences between the size of different pourers' cupfuls are inherent in the total and affect the "equivalent cup" values obtained but do not have to be assessed individually during every measuring. Thus, the two methods require similar adjustments and produce the same final result, but the apparently more direct method requires a good deal more work in the field.

Table 14. "Equivalent Value" of a Cup of Polystyrene pellets[42]

VG R 22 (1979)	50 cups − 50 50 cups + 30 (51 cups − 460 =) 50 cups + 65		
Average	50 cups + 15	Jar held 26,200 ml.	(App. 2, Table 9)
	50 cups may be equated to	26,185 ml.	
	1 cup may be equated to	523.7 ml.	
VG R 23 (1979)	50 cups − 435 50 cups − 485		
Average	50 cups − 460	Jar held 25,650 ml.	(*ibid.*)
	50 cups may be equated to	26,110 ml.	
	1 cup may be equated to	522.2 ml.	
VG R 24 (1979)	48 cups − 250 48 cups − 150		
Average	48 cups − 200	Jar held 24,900 ml.	(*ibid.*)
	48 cups may be equated to	25,100 ml.	
	1 cup may be equated to	522.9 ml.	
VG R 33 (1979)	48 cups − 25 48 cups − 110		
Average	48 cups − 70	Jar held 24,850 ml.	(*ibid.*)
	48 cups may be equated to	24,920 ml.	
	1 cup may be equated to	519.2 ml.	
MΣ 637	47 cups − 450 47 cups − 315 47 cups − 225		
Average	47 cups − 330	Jar held 24,480 ml.	(App. 1, Table 7)
	47 cups may be equated to	24,810 ml.	
	1 cup may be equated to	527.9 ml.	
VG R 23	49 cups 49 cups − 45		
Average	49 cups − 25	Jar held 25,650 ml.	(App. 2, Table 9)
	49 cups may be equated to	25,675 ml.	
	1 cup may be equated to	524.0 ml.	
VG R 24	48 cups − 60 48 cups − 275		
Average	48 cups − 170	Jar held 24,900 ml.	(*ibid.*)
	48 cups may be equated to	25,070 ml.	
	1 cup may be equated to	522.3 ml.	

greater than Mouliates 1979, and the figure for VG R 23 was actually about 90 ml. lower. Nevertheless, we would not try to state the "equivalent value" of our cup of polystyrene pellets used in measuring a full-size Rhodian jar in the late 3rd century B.C. any more precisely than as between 515 and 530 ml., and in calculations elsewhere in this paper we have rounded off 523.2 to 525 ml. In comparing means of groups obtained by polystyrene measuring with means obtained by water measuring there may clearly be an imprecision of, on occasion, up to ± *ca.* 1½%.

[42] For VG R 22 the cup is taken as 525 ml.; cf. note 35. If this slight circularity offends, set out the other calculations first, obtain the values for the cup as *ca.* 525, and *then* deal with VG R 22.

APPENDIX 4: Polystyrene Measurements of hôtel de Soleil Jars

All 137 amphoras found in the course of laying foundations for the Hôtel de Soleil had been broken and were mended, so that we could not, unfortunately, measure even one of them with water. We filled 133 jars that had mended up well or fairly well with polystyrene pellets, patching those that had small pieces missing with plasticine, tape, and filing cards, and even rebuilding a few largely destroyed upper necks in cardboard (applied from the inside), but the absolute values of the figures we obtained in cupfuls of polystyrene have to be calculated from the equations in Table 14 (which are all but one for Villanova jars a full generation later), of which heights and depths are comparable but diameters nearly 2 cm. less and the profile of the body slightly altered in addition (see Pl. 80). We have carried over from that discussion the "equivalent value" of a cupful of polystyrene (for full-size Rhodian jars *ca.* 250–200) as 525 ml. but emphasize the caveat entered there that the right "equivalent value" in a given case might be as low as 515 or as high as 530 ml. (perhaps even slightly more divergent for jars of a slightly different shape, as here). In addition, Table 10 illustrated the measuring error of a single result obtained with polystyrene: the mean of the ranges of pairs of results obtained by the same measurer on the same jar was *ca.* 160 ml., and a range of a third of a liter would not be impossible. In short, a single result is not worth stating in isolation to closer than a quarter liter and should not be relied on to be less than half a liter in error.

With 134 specimens, 123 of them bearing one of four fabricants' stamps, however, one might hope that the mean and even the range of the capacities of jars produced by one pottery in the year of the eponym in question, Pausanias, *ca.* 240–230, would emerge with much greater precision. Here, measurements by pouring cause particular complications (Tables 11–13), and one has to allow also for slight systematic variations in results by cupful from measurer to measurer and occasion to occasion. Since our "equivalent value" for the cup of polystyrene is based essentially on Mouliates 1979 results by cupfuls, we have reduced 1979 poured results and Mouliates 1980 results by 300 ml. to make them roughly comparable (cf. Appendix 3, p. 313). It was much less clear what should be done with other results (e.g., Zimmerman 1980, Angelinakes 1981), and in particular how to combine repeated measurements on different occasions. To omit the jars in question would be misleading since the remeasured jars are mostly those for which the initial result appeared exceptional. To discuss each estimate in detail would overburden the reader with conjecture. What we have done is to formulate a "best guess" for each jar and incorporate it in the averages. The fabricant most affected is Kreon, who has the fewest surviving jars, and the guesses in his case are detailed by way of example.[43] The mean that we finally posit for each fabricant is in fact very close to the adjusted mean of the poured measurements, so that the details of the "best guesses" do not in fact affect the general picture. The amount by which the means of the jars of the various fabricants differ is noteworthy and increases one's suspicion that the Hôtel de Soleil deposit may be of jars re-used for other purposes than carrying wine because they were found unfit (see footnote 17 above for other reasons to suspect the deposit). This would also account for the occasional jar that definitely falls more than

[43] The 6 jars of Kreon listed as "other" are A56 (ΜΣ 382): 53 cups − 250 = 27,575 (Zimmerman 1980), not adjusted; A70 (ΜΣ 447): 57 cups − 425 (1979 poured), 55 cups − 425 (Zimmerman 1980), and 56 cups − 180 (Angelinakes 1981), taken as 56 cups − 300 = 29,100; A173 (ΜΣ 322): 49 cups − 440 (Angelinakes 1979), 49 cups − 415 (Zimmerman 1980), 49 cups − 200 (Angelinakes 1981), taken as 49 cups − 350 = 25,375; A183 (ΜΣ 333): 59 cups − 100 (1979 poured), 58 cups − 270 (Manoles 1981), 56 cups − 125, and 57 cups − 470 (Zimmerman 1980), taken as 57 cups = 29,925; A216 (ΜΣ 350): 50 cups − 295 (Angelinakes 1979), 49 cups − 50 (Zimmerman 1980), taken as 50 cups − 400 = 25,850; A217 (ΜΣ 349): 51 cups − 250 (Angelinakes 1979), 51 cups − 60 (Mouliates 1980), taken as 51 cups − 300 = 26,475. Of these A70, A173, and A183 are more than 1½ liters from the mean of 52 cups − 100 = *ca.* 27.2 liters.

Table 15. Summary of Polystyrene Results for "Hôtel de Soleil" Fabricants

Fabricant	*Poured*	*Mouliates Cups 1979*	*Mouliates Cups 1980*	*Other*
DAMONIKOS				
no.	33	5	5	4
mean	27,215	26,432	27,442	
mean adjusted to 1979	26,915		27,142	
The mean of all 48 measurements after adjustment: 26,901 ml. or *26.9 l.*				
KREON				
no.	8	1	1	6
mean	27,650			
adjusted to 1979	27,350			
The mean of all 16 measurements after adjustment: 27,202 ml. or *27.2 l.*				
MIKYTHOS				
no.	13	3	2	13
mean	28,048			
adjusted	27,748			
The mean of all 31 measurements after adjustment: 27,815 ml. or *27.8 l.*				
XENOTIMOS				
no.	18	2	—	8
mean	27,993			
adjusted	27,693			
The mean of all 28 measurements after adjustment: 27,648 ml. or *27.6 l.*				

a liter and a quarter from the mean. Given the margin of error of polystyrene measuring, we have counted those that have a single measurement more than 1⅔ liters from the mean or repeated measurements leading to an estimate more than 1½ liters from it: Damonikos 4, Kreon 3, Mikythos 3, Xenotimos 0.[44] At the same time, if four different fabricants made batches with means from 26.9 to 27.8 liters, even if Mikythos' and Xenotimos' batches were condemned, let us say, for containing jars that were too large and Kreon's for erratic capacities (from 25.4 to 29.9 liters; see footnote 43), and Damonikos for misstamping (and these are mere speculations), it still seems likely that they were aiming at a mean near 27.3, not some quite different target, and that is the mean of the whole group (27.3). Nor are we sure that they were condemned.

APPENDIX 5: MEASUREMENTS OF KLEISIMBROTIDAS–THEUPHANES JARS

Capacity figures given above the single line are water results adjusted as described in Appendix 1; those below it are polystyrene results treated as described in Appendix 3, with Mouliates 1979 results by cupful unaltered, 1979 poured and 1980 Mouliates results reduced (and marked "p" or "1980") by 300 cc., and other results left unaltered but marked A (Angelinakes 1981) or O (other). Where we have more than one result for a jar there is a double line beneath them and then an estimate based on the figures above (see Appendix 4). All estimates are rounded to 50 ml.

[44] Nine of the 11 remaining jars in the 134, 3 of a *fabricant Pausanias* in the year of the eponym Pausanias, the rest with illegible or lost stamps or no stamps at all, range from *ca.* 26.0 to *ca.* 28.2 liters: one unstamped jar (A220 [ΜΣ 342], *ca.* 24.7 liters) and one jar of the much earlier year of Eukles (above, footnote 17, A48 [ΜΣ 387], *ca.* 23.6 liters) were smaller.

Table 16. Capacities of Kleisimbrotidas–Theuphanes Jars

Inv. No.	*Capacity*	*H*	*Depth*	*Dmax*
A23 (ΜΣ 469)	______	0.785	0.734	0.360
	27,300			
A24 (ΜΣ 473)	______	0.783	0.738	0.353
	26,000 p			
A25 (ΜΣ 472)	______	0.787	0.729	0.356
	28,000 p			
	27,615 1980			
	27,725 1980			
	28,075 A			
Estimate	27,800			
A26 (ΜΣ 477)	26,385	0.772	0.724	0.357
	26,690			
Estimate	26,450			
A27 (ΜΣ 478)	25,175	0.770	0.729	0.349
	25,350			
	25,280			
	25,345			
	25,315			
Estimate	25,300			
A28 (ΜΣ 470)	______	0.778	0.725	0.357
	26,600 p			
A29 (ΜΣ 467)	26,515 1980	0.777	0.733	0.349
	26,560 1980			
	26,725			
	26,550			
A30 (ΜΣ 468)	______	0.772	0.721	0.350
	25,245 p			
	25,425 1980			
Estimate	25,350			
A31 (ΜΣ 474)	______	0.782	0.731	0.354
	25,670 p			
A32 (ΜΣ 476)	25,660	0.778	0.731	[0.358]
	25,675			
	25,705			
	25,880			
	25,735			
	25,855			
	25,820			
	25,860			
	25,840			
Estimate	25,750			

Inv. No.	*Capacity*	*H*	*Depth*	*Dmax*
A33 (ΜΣ 471)	(25,855) + 175 = 26,030 25,900 p	0.782	0.726	0.352
Estimate	26,000			
A88 (ΜΣ 475)	—— 25,620 p	0.773	0.722	0.353

DESCRIPTION OF JARS SHOWN ON PLATE 80

a. A64 (ΜΣ 424)

Height: 0.801 m. capacity: 24,200 ml.
Depth: 0.737 m.
D(iam.)max: 0.358 m.

a.1 rectangular stamp ᾿Επὶ Παυ-σανία

a.2 rectangular stamp Μικύθου ᾿Αγριά[νου]

From the Hôtel de Soleil deposit (see footnote 10 above).

b. A33 (ΜΣ 471)

Height: 0.782 m. capacity: 26,000 ml.
Depth: 0.726 m.
D(iam.)max: 0.352 m.

b.1 circular stamp ᾿Επ᾿ ῾Ιερέως Θευφάνευς rose

b.2 circular stamp Κλεισιμβ[ροτ]ίδα ᾿Αρταμ̣ι̣τ̣ί̣[ο]ν̣ rose

From Οἰκοδομή Παπαγεοργίου "λάκκος" (see footnote 13 above).

c. VG R 35

Height: 0.784 m. capacity: [26,650] ml.
Depth: – –
D(iam.)max: 0.352 m.

c.1 rectangular stamp ᾿Επὶ Κρατίδα Θεσμοφορίου

c.2 rectangular stamp Δίσκου

c.3 secondary stamp 

From the Villanova deposit (see footnote 5 above). The secondary stamp, **c.3**, is on the same handle as stamp **c.1**, as may be seen in the photograph. For a previous publication of this jar, see V. R. Grace, "The Canaanite Jar," *The Aegean and the Near East (Studies Presented to Hetty Goldman)*, p. 108 and pl. XI, nos. 9–11.

P. M. Wallace Matheson
M. B. Wallace

Toronto, Ontario

University of Toronto
Department of Classics
Toronto, Ontario M5S 1A1

a. A64 (ΜΣ 424)
Hôtel de Soleil deposit

a. 1

a. 2

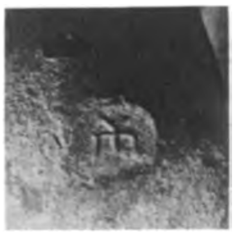
b. 1

b. 2

b. A33 (ΜΣ 471)
Οἰκοδομή Παπαγεοργίου
"λάκκος"

c. VG R 35
Villanova deposit

c. 1



c. 3

c. 2

Rhodian amphoras of the second half of the 3rd century B.C.

P. M. Wallace Matheson and M. B. Wallace: Some Rhodian Amphora Capacities