THE LINEAR B INSCRIBED STIRRUP JARS AND WEST CRETE

Prefatory Note

The four authors of this paper have worked in close consultation throughout the project, and present a joint result rather than so many separately initialled sections. Catling has most responsibility for the archaeological matter, Jones for the analytical work, Cherry and Jones for the interpretation of the results of the analyses and Killen for the epigraphic comment.

It must be noted that a single series of numbers, 1-108, is used throughout this paper to distinguish the test samples. The significance of these numbers is made clear in the Catalogue and Concordances.

Introduction

Fifteen years ago H.W. Catling and Mrs A. Millet (C and M) published in *Archaeometry* 8 a paper entitled "A Study of the Inscribed Stirrup Jars from Thebes" in which the authors presented the results of analysing by optical emission spectroscopy (OES) samples of clay taken from 25 large stirrup jars found in 1921 by A.D. Keramopoulos in the excavated remains of a Mycenaean building at Thebes.[1] Eighteen of these stirrup jars bore inscriptions in the Linear B script painted before the vases were fired. C and M also offered an archaeological explanation of their findings, suggesting most of the jars came from Crete, in all probability from Palaikastro and Zakro, at the extreme eastern end of the island.

It is instructive to try to understand why this particular inter-disciplinary project was undertaken when, where and how it was. At the beginning of the 1960's the University of Oxford was the focus of a titanic archaeological dispute (still, in the minds of some, unresolved). At the centre of the dispute were the clay tablets found by Sir Arthur Evans from the first days of his excavation at Knossos.[2] The dispute arose over the archaeological

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The following abbreviations are employed in addition to those in standard use:

AAA	*Athens Annals of Archaeology* = *Archaeologika Analekta ex Athinón* (Athens, 1968 –)
CIV	A. Sacconi, *Corpus delle Iscrizioni Vascolari in Lineare B* Incunabula Graeca LVIII, (Rome, 1974)
GAC	R. Hope-Simpson and O. T. P. K. Dickinson, *A Gazetteer of Aegean Civilization in the Bronze Age, Vol I: The Mainland and the Islands* SIMA LII, (Göteborg, 1979)
VIP	J. Raison, *Les Vases à Inscriptions Peintes de l'Age Mycénien*, (Rome, 1968)

Non-bibliographical abbreviations

C and J	H. W. Catling and R. E. Jones
C and M	H. W. Catling and A. Millett
FL	The Fitch Laboratory for Archaeology in the British School at Athens
ISJ	Inscribed stirrup jar
OES	Optical Emission Spectroscopy
OL	The Oxford University Research Laboratory for Archaeology and the History of Art
SJ	Stirrup jar

[1] The literature is very extensive; accounts of this discovery are best summarised in *VIP*.

[2] L.R. Palmer and J. Boardman, *On the Knossos Tablets* (Oxford, 1963) provides a full account.

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circumstances in which these tablets were found, which, in their turn, affected the date of the tablets. Very persuasive arguments in favour of a late date (c.1200 BC, or even later) were championed by Professor L.R.Palmer (at that time Professor of Comparative Philology in the University of Oxford); these arguments were challenged with equal vigour by archaeologists, many of them Oxford-based, who defended with cogent and detailed argument a position that the tablets belonged to a palace that was destroyed c.1400 BC, up to 200 years earlier than the date proposed by Palmer.

One of the elements in the controversy that deserves mention is that in 1939 and again in 1952, Carl Blegen at Pano Englianos in SW Messenia had found a substantial archive of tablets, similar in many ways to the Knossos documents, in a context he dated to the end of the thirteenth century BC.[3] No serious attempt has ever been made to challenge this date. The wide interval between the dates of the contexts in which the Knossian and Pylian texts were discovered seems to have been almost the strongest factor in stimulating Palmer's initial curiosity over the exact circumstances in which Evans had found his texts.

Although it was not until 1939 that tablets inscribed in Linear B were first found on the Greek Mainland, the first stirrup jar with a painted inscription had been found as early as 1903 at Orchomenos by the German excavators, only three years later than Evans found his first tablets at Knossos.[4] Fragments of several more were found at Tiryns in the German excavations of 1909-10; as we have seen, a large group of complete and fragmentary jars were found in 1921 at Thebes by Keramopoulos.

After the Ventris-Chadwick proposals for the decipherment of Linear B had gained acceptance and scholars turned to the task of interpreting the newly deciphered texts, the inscribed stirrup jars (ISJs) were not overlooked. It was emphasised, in particular by L.R. Palmer, that on many of the Theban ISJs place and personal names may be read. Several of these names occur in Knossian texts sugggesting at once that Crete might be the source from which some, at least, of the ISJs came.[5] Moreover, very close analysis of the relevant Knossian texts suggests that the places named lie in West Crete.[6]

The potential importance of the ISJs for an understanding of Aegean history in the Late Bronze Age is very considerable; given the dispute over the date of the Linear B archive at Knossos, it becomes a matter of exceptional importance that the source from which they came should be correctly identified. It is almost equally important to be able to date the contexts in which the ISJs were found. This last point will be elaborated below.

So far we have only explained the archaeological-epigraphic elements at work in the 1960's that led to the ISJ analysis project of 1965. Almost at the very moment that Palmer started to publish his views on the date of the Knossian archive, work was getting under way in the Oxford Laboratory for Archaeology and the History of Art (acting on the initiative of M.S.F. Hood) to explore the possibility of identifying provenance among Late Minoan and Mycenaean pottery by the use of OES. A brief account of the potential of this approach and a preview of some of the early results were published in 1961 by Blin-Stoyle, Catling and Richards in *Archaeometry* 4, and in 1963 the same authors published in *BSA* 58 a more detailed account of these and other results. Despite certain areas of disappointment, the application of OES to the solution of Aegean provenance problems seemed to have much to offer. To be able to distinguish between the decorated pottery of Crete and that from the

[3] C. W. Blegen and M. Rawson, *The Palace of Nestor* I (Princeton, 1966); see also E. L. Bennett and J. P. Olivier, *The Pylos Tablets Transcribed* (Rome, 1973).

[4] *VIP* 118-20.

[5] M. Ventris and J. Chadwick, *Documents in Mycenaean Greek*[2] (Cambridge, 1973) 212; L. R. Palmer, *The Interpretation of Mycenaean Greek Texts* (Oxford, 1963).

[6] See, for instance, L. R. Palmer, Kadmos x (1971) 70-86; *idem*, *Kadmos* xi (1972) 27-46; *idem*, Kadmos xii (1973) 60-75.

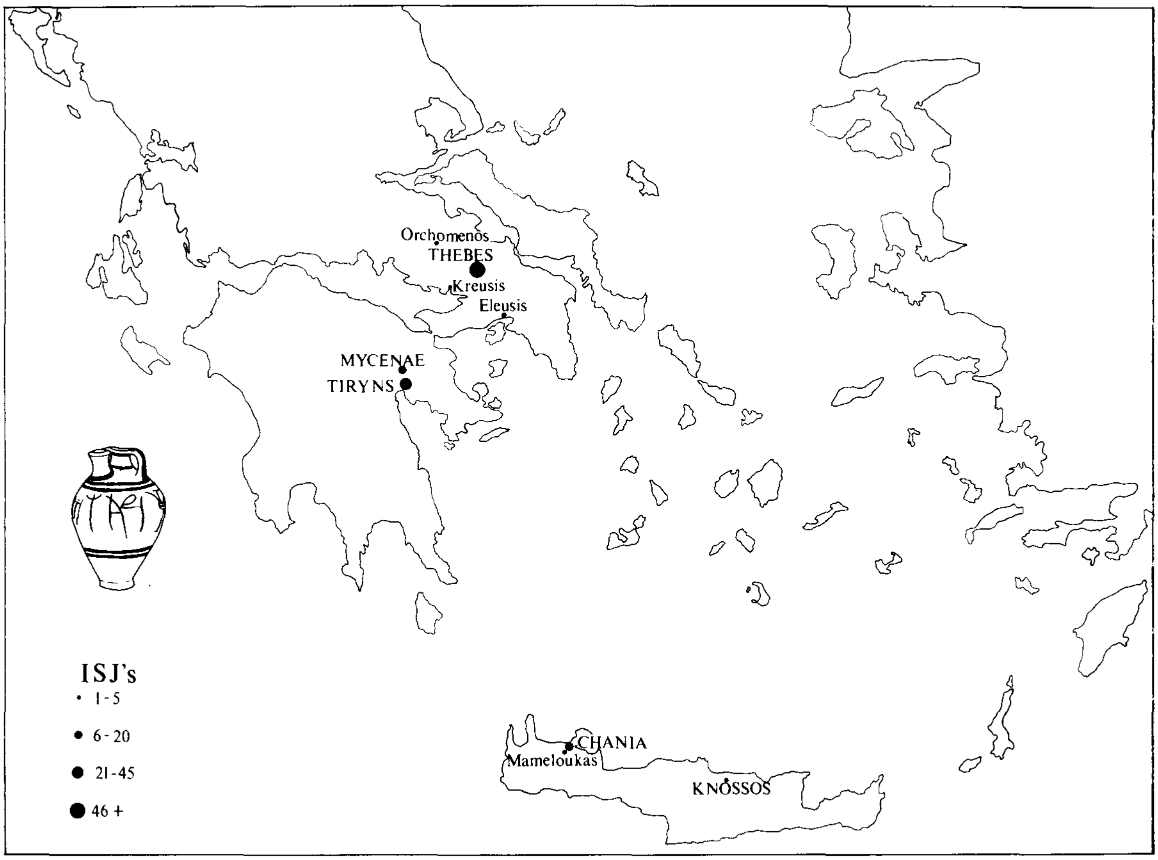

FIG. 1 Distribution map of the ISJs.

Mycenaean heartland in the Argolis seemed a great gain; when to that was added the identification of distinctive clays in other parts of Crete, on Melos, on Rhodes and in Euboea, it is not surprising that the protagonists of OES were anxious to apply the method to specific archaeological problems.

Late in 1964, as a result of a suggestion made by L.R. Palmer to E.T. Hall, Director of the Oxford Research Laboratory, Catling and Millett visited Thebes, where thanks to the generosity of the Greek authorities, in particular Professor N. Platon and Mrs Evie Stassinopoulou-Touloupa, the 25 jars already referred to were sampled, and a valuable Theban control collected from recently excavated material. The results of this work were published less than twelve months later. In this report the eighteen inscribed jars were attributed to Crete, and in particular to *East* Crete, where apparently identical clays had been isolated at Zakro and Palaikastro.

As is explained in detail below, under close scrutiny, the Catling-Millett ISJ publication revealed certain serious weaknesses. Nor were the results greeted with acclaim by those Linear B scholars most intimately involved with Minoan topography, who were quick to point out that *East* Crete made little sense as the origin of the ISJs, though *West* Crete would have been another matter. To C and M, very quickly, it was clear that a far wider-reaching investigation

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was required, one that would analyse samples of a much larger number of the known ISJs, and take account of a more widely chosen background of control material with which to try to match the results.

When C and M's results were published no ISJs had been found in Crete, a fact which for some cast doubt on the likelihood that anywhere in Crete could be their source of manufacture. Unknown to C and M, however, in 1964 Mr Yannis Tzedakis had found the fragment of an ISJ in his excavations at Chania, Kastelli (this is **74** in our catalogue below), the first of fifteen ISJ fragments to come to light in Chania both in Mr Tzedakis' excavations and those he undertook in collaboration with the Swedish Institute in Athens.[7] Furthermore, in 1968, Mr M.R. Popham recovered a nearly complete ISJ at Knossos at his excavation of the so-called Unexplored Mansion, adjoining the Little Palace.[8]

The publication of two monographs concerning ISJs in 1968 and 1974 respectively gave fresh impetus to work on the subject. The earlier, Jacques Raison's *VIP* sought both to present the known material more fully than had previously been possible and to offer archaeological conclusions concerning its interpretation. Though suitably cautious, he was more attracted to the proposal that most storage SJs and ISJs were made where they were found. He took issue with C and M over their interpretation of their results, and, more generally, in an appendix to *VIP*, cast doubt on the validity of some of the basic principles of composition and provenance work. C and M replied to this in a paper published in *Archaeometry* 11 in 1969, attempting to defend their position and to explain afresh the arguments that had led them to identify ISJ clay with East Cretan clay. The second monograph, Anna Sacconi's *CIV*, had rather different objectives. It offers an ISJ corpus, complete up to its publication in 1974, in which 141 items are listed, site by site, illustrated by very careful drawings and good photographs. Sacconi produces an edition of the text of each item, following the code of practice for transliteration and the use of diacritical signs agreed at the Wingspread Convention of 1961. *CIV* is an admirable and indispensable accompaniment to any ISJ work: the debt to it of this present paper will be apparent.

With the establishment in 1974 of the Marc and Ismene Fitch Research Laboratory in the British School at Athens, the focus of Aegean pottery provenance work by means of OES largely shifted from Oxford to Athens. The question of ISJ provenance was reopened, and in 1977, in *Archaeometry* 19, Catling and Jones (C and J) published the results of reanalysis of the eighteen Theban ISJs involved in the C and M 1965 study. They considered these results in the light of Chania controls, that had by that time been established. Moreover, with the help of Mr Yannis Tzedakis and Mr Eric Hallager, it had been possible to sample the Chania ISJs as well. C and J decided that there was a far closer correspondence between the Theban ISJs and the Chania controls than that argued for twelve years before by C and M for the East Crete controls. They concluded, therefore, that Chania must be regarded as the most likely source of the Theban ISJs as it evidently also was for a large majority of the Chania ISJs themselves. In their report they remarked, "For Anne Millett, it should be noted that analyses she subsequently made . . . of material from Chania had caused her to consider Chania a more probable source of manufacture than East Crete. It is particularly unfortunate that circumstances obliged her to discontinue her Oxford research before her work in this direction had been completed".

As C and J's 1977 paper was going to press (it was felt essential to publish the correction at the earliest opportunity) plans were already afoot for a more extensive and more sophisticated

[7] Chania finds are described and discussed by E. Hallager, *Op. Ath.* xi (1975) 53-6.

[8] *Kadmos* viii (1969) 43-5.

SJ project that should involve the analyses of as many examples as possible. With the help of many people, to whom reference will be found in the Acknowledgements, this objective has been partly realised and the results are set out in this paper. Unfortunately we have to say "partly realised", since it did not prove possible to obtain analyses of the full complement of ISJs. This arose for a variety of practical reasons which need not concern the reader. Suffice it to say, that if circumstances permit, the items at present missing will be analysed as soon as practicable and presented as a short supplement to this paper in a future issue of *BSA*.

Are ISJs *really* of such importance that further work and publication of the type attempted here is necessary or desirable? No single or easy answer can be given. Some insight into the importance attached to the original analytical work has already been given, from which it should be clear that fateful conclusions depend upon knowing where and when all ISJs were made. This work is important, however, for quite a different reason. To some degree it is a test of the credibility of OES as a continuing technique in composition and provenance work. It is much clearer in 1979 than it was in 1965 that no other Aegean pottery problem potentially capable of solution by analytical methods has so much promise as the ISJs. Not only do the 140-odd ISJs and fragments provide a significant population upon which to work, not only is there now a substantial corpus of source material from Crete itself, the Mainland and the islands against which to compare the ISJ compositions, but the ISJs themselves provide a control upon the validity of the interpretation based on the analytical results (we do *not* include in this context the views of Linear B scholars concerning Minoan topography, already mentioned). There exist a number of fairly obvious internal groupings among the ISJs, based not only on the text of the inscriptions, but on the different ways in which they are placed on the jars, as well as the more obvious archaeological features of form and technique. The possibilities of this type of characterisation of the ISJs were appreciated by Raison in *VIP*, and, although his groupings need not necessarily be regarded as sacrosanct in every detail, they serve as a very convenient independent criterion for judging the validity of the analytical groupings. As will be seen below, there is a very striking correspondence between these groupings and those based on epigraphic-typological grounds. Before proceeding with the presentation of the results, however, it is necessary to expand a little on the background to the problem and to review recent work on this material.

Review of the Problem

C and M's paper addressed itself, as has already been mentioned, to an investigation of composition and provenance of some of the inscribed jars from Thebes. At the time these analyses were undertaken, the OL's 'pottery map' of Greece consisted of some 20 sites on the Mainland and Crete which were thought likely to have been production centres, and samples of the local Late Bronze Age pottery had been analysed from each of them (usually 20 sherds, but 40 for Mycenae and Knossos).[9] Composition types were determined for individual sites or—as with the Peloponnese or central Crete—regions. Thebes was among the initial sites investigated in this way and its pottery compositions appeared, on the basis of a purely visual inspection of the data, to fall into two groups, one of which, fortuitously but unfortunately, was paralleled closely by those of central Crete termed Type B. Further work was deemed to be necessary to clarify the situation and 20 additional sherds from the 1964 Thebes excavations were analysed. While the results merely consolidated the earlier findings, careful re-examination of those Knossos and Thebes compositions which appeared to be indistinguishable on the basis of the 9

[9] Catling, Richards and Blin-Stoyle, *BSA* lviii (1963) 94-115.

elements routinely measured indicated that germanium was present in very low concentrations (c.10 ppm) in the Theban pottery, but apparently absent in the Cretan: on this basis, a distinction was drawn between Type B on Crete and Type B (designated B*) at Thebes. The analysis of the test material itself in C and M's study—25 ISJs from Thebes—suggested the presence of 4 composition types. Millett suggested that one set of ISJs (C and M nos 1-12) be attributed to a Zakro composition and a second set (C and M nos 13-18) to a Palaikastro composition; of the remainder, five were attributed to Thebes itself and two were tentatively matched with the Peloponnesian (Type A) composition. With the limited data available to them, therefore, C and M felt able to conclude that the east Cretan centres were likely to have been the principal producers of the ISJs found at Thebes. Some support for this somewhat surprising result could be found in the fact that all the analysed examples with the inscriptions *wa-to* and *O-du-ru-we* (placenames also occurring on the Knossos tablets, but not on Mainland Linear B tablets) belonged to the imported east Cretan class, while the locally produced jars bore only short inscriptions or had none at all. To some scholars this was decisive confirmation: Chadwick,[10] for example, suggested in 1969 that "the Mycenaean name of Zakro was *Odrus* (cf. Ὀδρύσαι), of Palaikastro *Wanthos* or the like".

If C and M's findings were, as they themselves admitted, unexpected, they also proved to be very controversial from the archaeological and scientific viewpoints. That a large majority of the Theban ISJs was imported was one of the fundamental conclusions of the analytical study and is now widely accepted, since it is obviously counter-intuitive to find Cretan toponyms painted on storage vessels made, used and broken at Thebes. This conclusion, simple in itself, was nevertheless strongly contended by Raison in his definitive corpus of Linear B inscribed vases.[12] Besides maintaining that stirrup jars were usually made where they have been found (thus apparently negating their commonly accepted function as storage jars ideal for transport), Raison questioned the premises on which the Oxford Laboratory's composition and provenance programme was based, and cast doubt on the validity of C and M's results in particular.

He maintained that the effects of the processes whereby the (Mycenaean) potters prepared their clay would tend to outweigh any localised traits of the clay in its natural state; in other words, the visual homogeneity of much of the fine pottery of Mycenaean Greece could well be the result of the use of potters' clay of rather similar composition. In this way, he explained the significance of the observed variations in composition of pottery from different regions not on geographical and geochemical grounds, but on the basis of the different working practices of potters. C and M replied in full to these criticisms in 1968;[13] they argued that the results of the composition survey work published in *BSA* in 1963 spoke for themselves: for example, the compositions of a range of pottery, not clay, from Mycenae and Knossos were significantly different. Furthermore, their case in favour of a geographical basis for this observed distinction was greatly enhanced by the results of analyses of modern clay and ancient pottery from Lefkandi in Euboea; their compositions were very similar. Most of Raison's objections can be seen to be based on a misunderstanding of some of the fundamental concepts of all

[10] J. Chadwick, *Minos* x (1969) 119.

[11] J. Chadwick, *Proc. Third Cretological Congress* I (Athens 1973) 41; L. Godart, *Minos* xii (1970) 418-24; *idem*, *Parola del Passato* 31 (fasc. 166) (1976) 118-22; A. Heubeck, *Athenaeum* 47 (1969) 144-53; J-P. Olivier, *Studi Micenei ed Egeo-Anatolici* ii (1967) 71-93.

[12] Raison, *VIP*; cf. also *idem*, review of C and M, *Revue des Études Anciennes* lxix (1967) 128-9; *idem*, Revue Archéologique lxxvii (1978) 79-86.

[13] H. W. Catling and A. Millett, *Archaeometry* xi (1969) 3-20.

composition and provenance work in archaeology; as such they lose much of their force.[14]

In a postscript to their 1969 paper, C and M were able to mention the recent discovery of fragments of inscribed jars at Chania and of a single inscribed jar fragment from the Unexplored Mansion at Knossos. With the exception of the inscribed cup found by Evans at Knossos in 1902,[15] these were the first such finds on Crete; this Cretan evidence has subsequently been enlarged by the excavation of additional fragments at Chania and a single piece from Mameloukas Cave, some 5 km outside Chania.[16] While these discoveries enhanced the plausibility of a Cretan origin for some, at least, of the Theban ISJs, their spatial bias towards western and central Crete raised serious doubts about the archaeological likelihood of C and M's attribution of the Theban jars to East Cretan sources; no Linear B inscriptions, at any rate, have yet been found east of Knossos.

Philological research in the past decade has moved steadily towards a similar conclusion. In 1970, Godart[17] noted the scribal and toponymic connections amongst the Knossos Co tablets, which put the place names *ka-ta-ra-i, o-du-ru-we, si-ra-ro, wa-to, ku-do-ni-ja* and *a-pa-ta-wa* into association, and argued that these localities were unlikely to be in central Crete; the fixes provided by *ku-do-ni-ja* and *a-pa-ta-wa* obviously point to the Chania region, and Godart suggested that the Zakro/Palaikastro area would have been environmentally incapable of supporting flocks on the scale recorded in the Co series. Sourvinou-Inwood[18] has made a spirited defence against this environmental argument, but it fails to account for the toponymic associations themselves. These were analysed in some detail by Palmer[19] as part of a more wide-ranging study of the Cretan Linear B place-names, and he concluded that *wa-to* and *o-du-ru-we* almost certainly lay to the west of Knossos. The whole question has now been placed on a firm footing by Wilson's[20] exhaustive statistically-based investigation of the links and groupings among the tablet place-names; his conclusion that the associations of his Group IV toponyms (which include *wa-to* and *o-du-re-we*) are only explicable if they were located in the west of the island has been strongly endorsed in a series of recent studies by Killen,[21] Chadwick,[22] Palmer,[23] Melena[23bis] and Cherry.[24] A further result of this work has been the realisation of the strong likelihood that the two other toponyms **56-ko-we* and *da-*22-to*, both of which appear on the ISJs but are not members of the "western group" listed in the Co tablets, are nevertheless located west of the central area. Indeed, all the evidence now suggests that "the administration of Knossos faced to the South and West rather than to the East" and that "the general pattern provides no evidence for contact between Knossos and the East of Crete".[25]

[14] Strangely, in view of his distrust of analytical techniques, Raison included the results of petrological and semiquantitative spectrographic analyses of three ISJs, three Mycenaean cups or bowls from the excavations at Thebes and seven large storage jars from Knossos, undertaken by Mlle. Bouchard. These results were indecisive, perhaps not surprisingly in view of the presence of Type B compositions at Knossos and Thebes, and little could be concluded.

[15] Sacconi, *CIV*, no. KN Z 1715; A. J. Evans, *BSA* viii (1901-2) 66-7, fig. 33.

[16] Tzedakis, *Kadmos* vi (1967) 106-9; *idem, Praktika* (1968) 133-38, Pl. 138; Sacconi, *CIV* 179-89; M.R. Popham, *Kadmos* viii (1969) 43-5, Pl. lc; E. Hallager, *Op. Ath.* xi (1975) 53-86; E. Hallager and M. Vlasakis, *AAA* ix (1976) 213-19.

[17] Godart, *op. cit.* (*supra*, n. 11).

[18] C. Sourvinou-Inwood, *Minos* xiii (1972) 130-6.

[19] Palmer, *op. cit.* (*supra*, n. 6).

[20] A. L. Wilson, *Minos* xvi (1977) 67-125.

[21] J. T. Killen, *Mycenaean Geography* (ed. J. Bintliff) (1977) 40-54.

[22] Chadwick, *op. cit.* (*supra*, n. 11).

[23] L. R. Palmer, 'Context and Geography' (Paper read at the *VIth International Colloquium on Mycenaean Studies*, Chaumont, Switzerland) 1975.

[23 bis] J. L. Melena, *Emerita* xlii (1974) 307-36; *idem, Minos* xv (1976) 133-63; *idem, Studies on some Mycenaean Inscriptions from Knossos dealing with Textiles* (*Minos Supplement* v) 1975.

[24] J. F. Cherry, unpublished study; application of computerised two-dimensional scaling techniques (as reported by J. F. Cherry, *Mycenaean Geography* (ed. J. Bintliff) (1977) 76-83) to toponym association data from the Knossos tablets (cf. Wilson, *op. cit.* (*supra*, no. 20) Appendix IV) strongly supports the clear separation of a western group of toponyms.

[25] Wilson, *op. cit.* (*supra*, n. 20) 108.

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One other new piece of information is particularly useful. On ISJ fragment KH Z 5 from Chania the signs [*de-so*] (to be restored as *ta-de-so* or *ta-*22-de-so*, probably a personal name) show scribal idiosyncracies which make it very likely that they were written by the same hand that wrote *ta-de-so* or *ta-*22-de-so* on TH Z 869, 870, 871, 872 and 876.[26] If so, this would imply not only the contemporaneity of the ISJs at Chania and Thebes but also a link of a very close kind.

All these arguments have provided increasingly strong grounds for supposing that C and M's East Cretan attribution of the Theban ISJs could not be correct, and several authors have reconsidered the original work on which it was based, searching for potential analytical or statistical errors. Criticisms of a more precise and carefully reasoned kind than Raison's were offered by McArthur and McArthur (1974)[27] and by Wilson (1976),[28] and their important papers may usefully be considered together since they both take issue over many aspects of the methodology employed by the OL. In particular they concerned themselves with weaknesses in the interpretation of the data and the steps leading up to an assignment of provenance.[29] The McArthurs' main criticisms centred on the inherent statistical bias of the research programme as a whole, resulting from non-random selection of samples and the inflexible use of an insufficiently wide range of elements for measurement. The original choice of 9 elements (Al, Mg, Fe, Ti, Mn, Cr, Ca, Na and Ni) stemmed from the results of the pilot study[30] which had confined itself to pottery from Knossos and Mycenae; the McArthurs challenged the assumption that the 6 elements which were found to be the most effective discriminants in that study (Mg, Mn, Cr, Ca, Na and Ni) would necessarily or similarly apply to the Aegean as a whole, citing the example (noted above) of the need in C and M's work to have recourse to the measurement of an additional element (Ge) to distinguish between the Type B compositions at Thebes and those at Knossos. Wilson pointed out that the successful assignment of pottery provenance is limited by the size and quality of the 'pottery map', ie. the extent to which reliable control groups for all relevant sites have been established, and maintained that this criterion had not been sufficiently fulfilled when C and M undertook their investigation. The assignment of provenance may also be hindered by the presence of sites with indistinguishable pottery compositions or by the presence of more than one composition type at a given site (which can in turn lead to the establishment of local sub-types on the basis of inadequate sample sizes). Consequently, Wilson regretted the lack of published information on how these problems had been tackled: his objections may be summarised as "insufficient comparative data, insufficient statistical techniques, and insufficient explanation of the deductive stages".

The approach to the analysis of composition data used by Millett and earlier workers at the OL was basically intuitive and visual, and, while now clearly outmoded, it must be remembered that much of this work predated the availability of fast computers and pre-written programmes for large-scale multivariate analysis, and the widespread application of quantitative techniques in archaeology. The compositions were classified by the visual similarity of element contexts displayed in histogram form, and groups were prepared from a set of sample compositions whose elemental constituents were deemed to be "more or less similar"; on the basis of data presented for Ca and Mg in the 1963 pilot study, elemental con-

[26] Killen, *op. cit.* (*supra*, n. 21) 46; Godart, *op. cit.* (*supra*, n. 11) (1976) 121; Hallager, *op. cit.* (*supra*, n. 7) 67.

[27] J. McArthur and J. McArthur, *Minos* xv (1974) 68-80; J. McArthur, *The Implications of recent archaeological discoveries in Crete and Thebes for the problem of dating and origin of the Theban Stirrup Jars* (Dissertation, Monash University) 1973.

[28] A. L. Wilson, *Archaeometry* xviii (1976) 51-8.

[29] A. L. Wilson, *Journal of Archaeological Science* v (1978) 219-36 discusses many of these points within a general framework.

[30] Catling, Richards and Blin-Stoyle, *op. cit.* (*supra*, n. 9).

centrations were taken to be normally, rather than log-normally distributed.[31] The mean, standard deviation and concentration ranges (set at what was considered to be an appropriate level of confidence, normally 80%) were then calculated. In the final stage, a test or test group composition was compared with the controls in order to determine the particular group(s) for which the maximum number of elements of the former fell within the 80% ranges of the latter. Wilson rightly either found fault with, or lack of detailed explanation of, most stages of this procedure and advised that these inappropriate, subjective univariate procedures be replaced by the techniques of multivariate analysis.[32] One particular telling point was noted by both Wilson and Raison: for none of the 18 Theban ISJs considered by C and M do all the elements fall within the concentration ranges of the groups to which they were assigned. While all elements will not always fall within their group ranges, the match between the individual ISJ compositions and the East Cretan compositions seemed very uneven and imperfect. Furthermore, C and M's explanation that this lack of fit resulted from experimental errors is simply inadmissible. Wilson examined this discrepancy by comparing the observed number of elements in the ISJ compositions that fell outside the East Cretan ranges with the probability, derived from the binomial distribution, that a given number of elements will fall outside the concentration ranges of their respective groups; he found the difference between observation and prediction to be statistically insignificant beyond the 0.01 probability level. Thus, his conclusion that C and M's attribution of the Theban ISJs should be considered unproven is incontrovertible, although it was perhaps not emphasised sufficiently that *of the limited control groups available to C and M at that time* the East Cretan ones did best match the ISJs—a conclusion of a very different kind, as Wilson noted.

The McArthurs also drew attention to the fact that composition groups had been formed on the basis of far too few samples which themselves may represent only a small proportion of the limited number sampled from the site as a whole; this inadequate characterisation of profile types led, not surprisingly, to group instability necessitating a major reorganisation when further samples were added to the analysis. Both these points are exemplified by the Palaikastro and Zakro composition groups. They expressed surprise at the large representation of Type B (central Crete) compositions among these new samples and called into question the archaeological criteria by which they had been selected. Like Wilson, the McArthurs attempted limited reanalysis of C and M's data, applying for the first time computer programmes for multivariate analysis. A Ward's method hierarchical cluster analysis applied to the standardised concentrations of each of the 9 elements measured in the 25 Theban ISJs was interpreted at first the 6-group and then the 4-group levels (b, below) and compared with C and M's groupings (a, below). In subsequent analyses they omitted data for the elements Al and Fe (since these were absent from C and M's profile graphs and were considered by them to hold little discriminating power), and the resulting groups (c, below) harmonize rather better with those of C and M. Further experimentation with multiple discriminant analysis indicated that a combination of the 5 elements Mg, Ni, Ca, Cr and Fe could account for around 90% of the variance between the 5 groups defined by C and M. The McArthurs offered little discussion of the significance of these results and their principal contribution to the problem was the demonstration of the utility of rapid, objective multivariate techniques for data analysis of this sort.

[31] This was probably a premature decision; cf. Wilson, *op. cit.* (*supra*, n. 29) 226-7.

[32] e.g. A. M. Bieber, D. W. Brooks, G. Harbottle and E. V. Sayre, *Archaeometry* xviii (1976) 59-74; R. Mertz, W. Melson and G. Levenbach, *Archaeo-Physika* x (1978) 580-96; P. A. Mountjoy, R. E. Jones and J. F. Cherry, BSA lxxiii (1978 143-71.

	(a)		(b)	(c)
Group I	ISJs 1-12	(F)	ISJs 1-4,6-12,15	ISJs 1-12
Group II	13-18	(O)	5	13-17,24-25
Group III	19,20,23	(B*)	13,14,16-18,24-25	18
Group IV	24-25	(A)	19-23	19-23
Group V	21,22	(Rogues)		

The publication of Wilson's paper coincided with the completion by the newly-established FL at the British School at Athens of an analytical study of the local wares from the Greek-Swedish excavations at Chania. Since the initial discovery in 1967 of fragments of ISJs at Chania, further examples appeared in the course of continuing excavation, bringing the total to 16.[33] The offer by the excavators to allow these fragments to be sampled for chemical analysis provided the FL with the motivation to include them with a reanalysis of the Theban ISJs 1-18 (ie. those attributed by C and M to East Crete). The aims of the work reported in 1977 by C and J were, therefore, unambitious in scope. Their data consisted of (a) control group compositions for Thebes and 3 well-defined groups from Chania, and (b) test material comprising the Theban ISJs previously examined[34] plus the new ISJs from Chania. All the data were obtained by the FL itself, no attempt being made to incorporate the OL composition data for the Thebes control or the Theban ISJs. On the basis of the traditional techniques of data interpretation (noted above), the Theban ISJ compositions were found to be divisible, principally by Ca concentration, into two groups (Theban ISJs 1-12 and 13-18), in agreement with the earlier analyses of C and M. These two groups, in turn, could be matched respectively with the Chania II and Chania III control groups, while both of them were clearly distinguishable from the Theban controls for all elements. The conclusions drawn from this limited study were duly cautious: "The Theban ISJ compositions can be collectively accommodated within the Chania characteristics. While this does not constitute proof that the Theban ISJs were made at Chania, it does, a least, provide strong evidence in favour of a west Cretan origin as an alternative to the east Cretan origin initially suggested by C and M." Even this conclusion was perhaps too strong, given that East Cretan material was not included in the study, precluding direct comparison of the merits of East versus West Crete as potential sources for the Theban ISJs; fortunately, however, it is also a conclusion that has not been negated by the results of the present, more comprehensive study.

These results from C and J's study were criticised in some detail in a further paper by McArthur in 1978.[35] She reiterated a number of the points made in her earlier joint publication concerning inherent weaknesses in the methodological approach of the OL & FL to composition and provenance studies, and noted that the restudy of the ISJs had failed to meet most of these problems:

[33] Refs. in n. 16 *supra*.

[34] The compositions of Theban ISJs 1-18 alone were published because (a) in the light of C and M's results they seemed to be the most relevant to the problem in hand, and (b) there was insufficient sample remaining of nos. 19, 24 and 25. Nos. 22 and 23 were reanalysed, but their compositions were not available for inclusion in the multi-variate analyses reported below; their compositions, which are discussed on p. 83, are given here:

C & M No.	TH Z	% age Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
22	943	16.0	7.4	10.5	1.00	0.104	0.075	15.7	0.87	0.054
23	944	15.5	7.0	9.0	0.80	0.086	0.073	13.3	1.40	0.042

[35] J. McArthur, *Archaeometry* xx (1978) 177-82.

1) the inflexible reliance of only 9 elements selected in a much earlier study,
2) the formation for some sites of control groups based on too few samples,
3) an unrepresentative coverage of potential source sites for control purposes,
4) the questionable validity of using certain statistical procedures on samples which were not randomly selected.

McArthur also drew attention to apparent discrepancies between the 1965 and 1977 compositional data for the Theban ISJs, indicating poor reproducibility of results over a 12 year period, and was prompted to ask whether this therefore invalidated *all* the earlier composition data. She suggested that a more flexible approach to the determination of control compositions be taken, and specifically that newly analysed data be added to a cumulative data bank which would facilitate the periodic reassessment and refinement of the compositional profile of individual sites, as well as the expansion of the 'pottery map'.

Two further papers must finally be mentioned. Fossey[36] published in 1978 a brief note highlighting points of interest to Boeotian scholars in these analyses. While in no way denying the great potential of physico-chemical techniques for archaeological provenance studies, he partly misconceived the purpose of C and J's study and its preliminary nature. He endorsed many of the earlier criticisms of the ISJ composition studies and noted a number of requirements for the future. These include the full publication of all the sample data reanalysed on the same calibrations, the inclusion of archaeological information about the sherds to allow stylistic comparison and chronological reassessment if necessary, the adoption on a routine basis of a rigorous statistical approach involving multi-element discrimination, and the submission of the material to alternative analytical techniques such as neutron activation analysis. Lastly, Wilson[37] has been stimulated by his consideration of the ISJ analyses to consider the question of elemental analyses of pottery in the study of its provenance from a wider perspective. His useful review of the problems and limitations of the technique suggests a number of methodological *desiderata* and sensibly emphasises the need for caution in reaching definite conclusions on the place of manufacture.

These, then, are the facts of the case. It is immediately clear, on the one hand, that the work on the ISJs has generated much discussion and controversy in archaeological circles owing to the interest and importance of the material. On the other hand, and quite separately, this study has come to represent in its aims a model of the type of problem to which the concept of composition and provenance may be applied; as such, the work has been elevated to a position from which the whole analytical programme of the OL & FL relating to provenance studies of Aegean pottery has been critically judged. To put it more succinctly, the ISJ investigation has become a 'test case'.

The work reported in the present paper was initiated as part of the FL's continuing programme of provenance studies and is intended to follow up and expand upon the work of C and J, as a further contribution to the study of Aegean ISJs. It also represents an explicit attempt to come to terms with some, at least, of the problems encountered in earlier studies, since this paper offers an obvious opportunity to reply to the criticisms summarised above and—wherever feasible and appropriate—to implement useful suggestions. Our aim, which is ambitious in scope, is to consider *collectively* the question of the origins of the ISJs from the mainland of Greece and from Crete; the study differs from previous work in its consideration of ISJs from several other sites besides Thebes and Chania, in the scale of the analytical

[36] J. M. Fossey, *Teiresias (Archaeologica)* (1978) 5.
[37] Wilson, *op. cit.* (*supra*, n. 29); cf. also H. Härke, *PZ* liii (1978) 165-276.

programme and in its heavy reliance on computer-based multivariate procedures. Table 1 lists all known sources of ISJs together with the number of examples found, as set out by Sacconi[38] in the updated corpus of 1974 which takes account of more recent ISJ discoveries unavailable to Raison in 1968; the corresponding number of ISJs analysed in the present study is indicated alongside as an indication of the scale of the sampling. It is necessary to bear in mind that the coarse ware stirrup jars of the LM III period, of which the ISJs form a class in their own right, are widely represented on the Mainland, and these uninscribed stirrup jars themselves offer many important questions of provenance which may relate to or parallel those of the inscribed jars. Thus, although this study is chiefly concerned with the inscribed jars, a number of plain and decorated jars have been included for reasons of their intrinsic interest or their relation to wider problems of provenance in the Aegean Late Bronze Age; these are included in the catalogue.

TABLE 1

Site	Sacconi ISJs	Addnl ISJs	Non ISJ Inscr. Sacconi	? Status	Pot Marks	Total No Anal.	Total ISJs Anal.	% Total ISJs Anal.
Mycenae	10	1*	1*	1*	—	7	5	45%
Tiryns	42	1*	1	—	1*	20	19	44%
Eleusis	1	—	—	—	—	1	1	100%
Kreusis	1	—	—	—	—	—	—	—
Orchomenos	1	—	—	—	—	1	1	100%
Thebes	68	1	—	—	8	42	34	49%
Knossos	1	—	1*	—	—	2	2	100%
Khania	15†	—	—	1	—	16	15	100%
Mameloukas	1	—	—	—	—	—	—	—
	140	3	3	2	9	89	77	54%

*Analysed in the current project
†This includes KH 23 which may have been *made* as a stopper.

ANALYTICAL PROCEDURES

Sampling. The material selected for analysis as part of the OL and FL's programmes of research on Late Bronze Age Aegean pottery has, for the most part, been from fine wares. Two methods of sampling have been used by these laboratories: (a) cleaning a portion of the sherd by removing paint, slip and weathered surfaces with a steel scalpel blade and breaking of a 50 mg chip which is ground to powder, (b) drilling with a tungsten carbide drill head to give c. 30 mg of powder, this being the technique normally adopted in the case of whole pots. Although method (a) is preferable to (b), the laboratories have usually been satisfied that samples obtained by either method have been representative of the pot or potsherd as a whole.[39] The stirrup jars, whose fabric varies from semi-coarse to coarse, have therefore presented a problem, and have had to be treated as a special case. An attempt was made to determine the minimum acceptable sample weight, obtained by either method, which could be taken to reflect the composition of the jar or jar fragment. Chips, each of 200 mg, from two

[38] Sacconi, *CIV*.
[39] But little or no data relevant to this point have been published by either laboratory in the past.

uninscribed stirrup jars from the House of the Wine Merchant at Mycenae were used to prepare powdered sub-samples of 30, 50 and 100 mg each, and the compositions of these sub-samples were compared. While the variations between the 50 and 100 mg samples were within the limits of total experimental error for all elements, those between the 30 mg samples on the one hand, and the 50 and 100 mg samples on the other, were up to 10% greater. It was decided, therefore, to take a sample of at least 50 mg wherever possible. In the event, however, conditions dictated that the majority of the samples be taken by drilling, and in most cases *at least* 30 mg of powder were collected. Duplicate drillings were also taken from **11**; the compositions (Table 2a) indicate that the discrepancies are only marginally larger than those expected for duplicate samples of a fine ware, and that they are largely accountable in terms of the random errors of the technique (except for Ca and Na).[40] These results and those obtained for the fine and coarse ware samples for some of the controls (especially Knossos and Palaikastro) lead us to believe that the spectrographic technique is at no great disadvantage in dealing with coarse wares and that 30-50 mg is an adequate sample.

All samples were obtained by drilling,[41] except **44, 72, 50, 6,** and **92** which were taken by scraping about 30 mg of powder with a steel scalpel blade, and **49, 96 – 106** and **70** which were obtained by breaking off a small chip. It should be noted that the fabric of two samples, **72** and **46**, both cups, contrasted markedly with the remainder in having a fine paste. The samples were given no pre-treatment until they were mixed with internal standard in readiness for arcing.[42] All the control samples were derived from a chip broken from the sherds.

Technique. The analyses were performed by optical emission spectroscopy as were those of C and M and C and J. The test samples, with the exception of some from Chania, were all analysed in one batch in order to maintain strict control over the uniformity of the analytical procedure.[43] The analytical precision may be judged from the average figures of the coefficient of variation of the elemental content determination (Table 2b); these have been obtained by regular multiple analyses of a Mycenae standard. The Knossos, Palaikastro and Athens control sample compositions were obtained at the same time as those of the test samples, whereas the remaining control samples were analysed at different times up to 4 years ago. For these latter samples, a careful check was clearly required on the ability to sustain long-term reproducibility of the data; this is considered next.

Long-term reproducibility of compositional profiles. Two methods were used to examine this important consideration:

a) The photographic plates bearing the spectra of Thebes and Chania test samples and the Thebes and some of the Chania control samples were 're-read' using the non-recording microdensitometer. Comparison between the new and the original results revealed that, with the exception of Cr which will be considered below, there was a net 3% change in elemental concentrations. Since we believe that the properties of the photoemulsion have

[40] Evaluation of the total experimental error is complex, and the following figures are merely estimates derived from a large body of data covering wide concentration ranges; *c* ± 15% of the determined Fe, Ti, Mn and Ni contents, *c* ± 20% of the determined Al, Mg, Ca and Na contents and *c* ± 20-25% of the determined Cr content. A fuller treatment of this matter will appear in a forthcoming review of pottery composition and provenance studies being prepared by REJ.

[41] A tungsten carbide drill head was used; an area on the cross section of the sherd, or, in the case of whole (restored) jars, on the base, was cleaned, and the first drillings discarded. A single hole was then drilled and powder collected. Some of the Theban jars had been heavily restored, and particular care was taken to avoid contamination with gypsum.

[42] Except for the clay samples which were crushed and dried at 110°C before analysis.

[43] The samples, whose spectra were recorded on a series of photographic plates, were calibrated with three Mycenae standards per plate.

[44] i.e. they were sub-samples.

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TABLE 2

	Percentage Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
(a) TH 11 α	19.5	5.5	8.5	0.97	0.100	0.056	20.0	1.52	0.044
TH 11 β	18.2	5.2	8.2	0.91	0.086	0.047	13.6	1.32	0.041
(b) Coefficient of Variation (%)	8	8	8	7	7	17	12	9	8
(c)% Δ	+ 25	+ 18	+ 2.9	+ 1	− 4.5	+ 43	+ 7.6	+ 11	− 12

% Δ: Mean percentage change of element contents determined from two sets of analyses of 8 Chania ISJs.

not altered over the four year period—or, if they have, the changes have been uniform over the spectral plate—this net change represents the errors involved in the reading of the plate and the manual processing of the data, especially the manual preparation of the calibration.

b) Eight samples from Chania, **74, 75, 81-84, 87** and **88**, originally analysed by C and J, were reanalysed using samples taken from the same batches obtained in 1976. Table 2c lists the mean percentage changes of the elemental contents (%△). The similarity between the old and new compositions with respect to the Fe, Ti, Mn, Ca, Na and Ni contents was sufficiently close to be able to use the original data with some confidence. This was not unfortunately the case for Al and Cr. There was a clear indication from the old and new Mg contents that the error in the determination of this element increased significantly below 2%; the discrepancy between the Mg contents of **74** and **75** (12%) was lower than the mean values of those of the remainder (21%). This line of investigation was taken a step further by re-examining 12 Theban jars originally analysed by C and M. They were resampled from the jars themselves and re-analysed at the FL; 8 of these (**2, 3, 4, 6, 8, 9, 15** and **16**) had already been re-analysed, using Millett's original samples, in C and J's restudy. For these, some major discrepancies between the new and old compositions were encountered, especially in Na and again in Cr and Al. This disturbing result is likely to be an instance of poor reproducibility, but it should be borne in mind that the new (1979) analyses were made on samples which had been placed in tissue paper and stored roughly in envelopes for over 10 years; our confidence in accepting these as reasonable samples in 1976 may well have been unfounded.[45] The measurement of Cr has for a long time been problematic and the reproducibility of its measurement has been correspondingly poor. One indication of this situation has been variability in the lower limit of detection for this element. At the time of C and J's re-analyses of Millett's Theban samples, the Cr calibration could adequately meet the demands of relative intensities (Cr/Li ratios) corresponding to Cr concentrations of 0.010%. As a result, the process of re-reading the old spectral plates has inevitably altered significantly the Cr contents of those samples whose originally determined Cr content was 0.010% or less. These changes may be associated with particular batches of spectral plates with altered emulsion properties, but this is as yet uncertain. The normally measured Cr spectral line at 3022 Å has been augmented for concentrations below about 0.030% by the line at 2843Å.[46]

In summary, there is evidence that the laboratory's analytical procedure can maintain reasonable long-term reproducibility of composition data for most elements, but it is equally

[45] The compositions of these eight Theban ISJ samples given in Table 3 are the *new* ones.

[46] This point will be discussed in more detail by REJ (*supra*, n. 40).

plain that the uniformity and regularity of this reproducibility is not absolute. This is, in fact, one of the points of contention raised by McArthur and further discussion will be incorporated below.

Analytical Results and Quantitive Analyses

The elemental compositions (percentage element in oxide form) of each of the inscribed and uninscribed vases which constitute the test samples are listed in Table 3; summary statistics for the control samples from each site are presented in Table 4. These data were considered in two ways, each quite independent: (a) by the traditional approach, adopted in all previous work of this kind by the OL & FL, of classifying and grouping samples on the basis of a visual assessment of compositional homogeneity, and (b) by computer-based multivariate classification and discrimination procedures. Since the present study inevitably invites comparisons with the results of the earlier studies and criticisms reviewed above, we include here the conclusions reached by method (a). However, while there is in fact a gratifyingly close correspondence between these conclusions and those suggested by computer analyses, it must be emphasised that the final inferences which we draw from this study depend on, and must be judged by, the results of the multivariate studies reported below.

Visual classification. Following the traditional approach of classifying composition by a visual assessment of homogeneity, the control samples were grouped (and in some cases sub-grouped) by site, and the mean and standard deviation of these groups calculated (Table 4). Applying the same method to the test samples on a site-by-site basis, composition groups were isolated, and their summary statistics are presented in Table 5. If one considers the test samples collectively, it is apparent that there exists a good deal of similarity between many of the composition groups such that these may be amalgamated. In this way, two classes of material designated α and β are to be distinguished on the basis of Ca concentrations. Moreover, both α and β exhibit clear differences in Mg, Cr and Ni contents from the Mainland site control samples and those from Knossos, implying that the origins of these two classes of test material do not lie in Knossos or any of the Mainland sites included in the study. Of the remaining two Cretan sites under consideration, Chania and Palaikastro, both α and β most closely fit the former, especially the Chania II and Chania III control groups. Thus, if the jars in classes α and β, which are listed in Table 6, did indeed have a provenance amongst the sites considered here, it would be legitimate to assign them to West Crete. The residual groups of test samples are more problematic, but the most economical interpretation, which is not contradicted by the elemental data, is to propose that they were made at their respective findspots (Table 6). **74** and **75** from Chania, however, may be Knossian, and **86** also from Chania cannot at this stage be placed.

Multivariate analyses. Since the results from spectrographic analysis comprise 9 elemental determinations on each of 108 test samples and 212 control samples (ie 2,880 individual bits of data), some use of automated techniques of data analysis was regarded as mandatory; as in our recent work[47] on the compositions of Marine Style pottery, the appropriate analyses were performed independently by one of us (JFC), using the computing facilities at the Universities of Sheffield and Manchester.[48] No attempt will be made here to justify the use, or explicate the

[47] Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32).

[48] As before, the ICL 1906S computer at Sheffield University and the CDC 7600 computer at Manchester University were used. Step-wise discriminant analysis, principal components analysis, t-tests, scatter plots and a variety of basic data listings and cross-tabulations were all produced within the packages SPSS 5 (Sheffield) and SPSS 6 (Manchester), using subprograms DISCRIMINANT, FACTOR, T-TEST, SCATTERGRAM and CROSS TABS; these are usefully documented in N. H. Nie, *et al.*, *Statistical package for the Social Sciences* (2nd ed., 1975). For cluster analysis, the program CLUSTAN was used; details in D. Wishart, *CLUSTAN IA User's Manual* (1969).

TABLE 3: *The Compositions of the Test samples*

*See explanation in Prefatory Note, p. 49 and Introduction to the Catalogue, p. 104

*Sample Cat. no.	Percentage Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
1 TH1	19.8	1.3	7.6	1.00	0.064	0.024	0.9	1.27	0.009
2 TH2	23.6	1.0	7.5	1.05	0.048	0.019	0.9	1.34	0.008
3 TH3	20.6	0.6	4.6	0.97	0.034	0.016	0.8	1.10	0.006
4 TH4	25.0	1.2	7.3	1.00	0.085	0.016	0.6	1.33	0.009
5 TH5	20.0	1.7	6.0	0.92	0.063	0.010	11.6	2.15	0.008
6 TH6	15.0	1.0	8.1	0.92	0.057	0.017	6.0	0.76	0.009
7 TH7	18.5	1.0	6.1	0.98	0.060	0.010	7.9	0.88	0.008
8 TH8	14.8	0.9	6.6	0.74	0.069	0.021	7.1	1.15	0.008
9 TH9	19.5	1.5	7.8	1.03	0.065	0.019	8.4	1.35	0.013
10 TH10	15.0	0.7	5.8	0.71	0.050	0.012	6.9	0.70	0.007
11 TH11	18.9	5.4	8.4	0.94	0.091	0.053	16.8	1.42	0.043
12 TH12	19.8	5.5	7.9	0.93	0.077	0.048	13.7	1.48	0.032
13 TH13	19.0	5.3	7.4	0.96	0.084	0.058	15.2	1.95	0.031
14 TH14	13.9	3.9	7.4	0.87	0.075	0.067	12.4	0.76	0.034
15 TH15	17.5	0.6	9.0	0.84	0.035	0.017	0.4	0.70	0.008
16 TH16	23.0	0.5	4.2	1.14	0.051	0.017	0.3	1.52	0.011
17 TH17	23.4	0.6	5.0	1.19	0.034	0.018	0.2	0.51	0.008
18 TH18	20.0	7.0	8.9	1.05	0.104	0.061	19.5	1.87	0.051
19 TH19	19.5	8.3	9.2	1.44	0.086	0.066	15.2	1.66	0.051
20 TH20	17.7	7.6	8.9	1.01	0.106	0.124	10.4	1.45	0.054
21 TH21	21.3	0.9	4.2	1.15	0.031	0.025	1.2	1.27	0.007
22 TH22	20.5	0.7	6.6	1.02	0.033	0.024	0.2	1.10	0.005
23 TH23	23.2	0.7	4.4	1.04	0.038	0.021	0.4	1.11	0.006
24 TH24	23.9	0.9	5.8	1.12	0.031	0.026	4.6	0.93	0.006
25 TH25	~25	1.6	5.6	1.34	0.081	0.026	12.3	0.70	0.018
26 TH26	~25	0.8	3.5	1.30	0.028	0.021	0.8	0.69	0.006
27 TH27	21.2	1.3	7.2	0.89	0.068	0.015	6.3	0.68	0.008
28 TH28	18.5	1.1	7.1	1.00	0.068	0.020	8.3	0.91	0.011
29 TH29	22.2	1.0	7.1	1.11	0.067	0.022	0.8	1.30	0.010
30 TH30	22.7	2.8	9.2	1.13	0.075	0.024	10.3	0.66	0.018
31 TH31	20.5	1.0	8.1	0.98	0.061	0.021	0.6	1.40	0.008
32 TH32	21.9	1.5	7.6	0.91	0.079	0.024	8.0	0.94	0.011
33 TH33	14.5	1.0	6.4	0.92	0.063	0.021	8.3	1.03	0.013
34 TH34	24.5	1.3	7.1	0.96	0.070	0.023	13.4	0.76	0.009
35 TH35	16.8	4.8	8.6	0.79	0.101	0.055	10.8	1.02	0.046
36 TH36	19.5	1.2	7.9	0.98	0.073	0.022	10.4	0.75	0.010
37 TH37	18.8	0.9	7.6	0.98	0.075	0.023	4.4	1.33	0.009
38 TH38	24.0	0.4	4.6	1.33	0.031	0.024	0.3	0.65	0.008
39 TH39	~25	1.3	7.1	1.04	0.077	0.019	10.6	0.84	0.012
40 TH40	21.7	1.1	6.1	1.02	0.072	0.017	12.7	1.65	0.009
41 TH41	22.2	3.4	8.0	1.01	0.165	0.033	15.2	1.02	0.029
42 TH42	21.4	3.8	8.2	0.91	0.085	0.069	15.5	1.70	0.038
43 OR1	19.5	0.9	7.5	0.83	0.197	0.017	6.7	0.76	0.011
44 EL1	18.5	1.9	7.9	0.78	0.053	0.035	7.3	1.25	0.027
45 MY1	17.0	1.5	7.0	0.88	0.048	0.023	5.6	1.21	0.011
46 MY2	19.0	3.1	8.6	0.75	0.080	0.033	16.5	0.70	0.034
47 MY3	18.5	3.8	8.8	0.78	0.097	0.054	18.0	0.74	0.034
48 MY4	14.0	3.2	8.7	0.78	0.080	0.043	15.5	1.83	0.036
49 MY5	18.3	5.3	9.3	0.89	0.077	0.060	14.7	1.46	0.035
50 MY6	13.0	4.0	8.1	0.72	0.080	0.056	9.2	1.46	0.035
51 MY7	18.2	3.0	5.8	0.76	0.102	0.033	20.0	0.90	0.027
52 TI1	21.2	0.8	7.1	1.02	0.078	0.013	7.7	1.00	0.008
53 TI2	~25	0.7	4.8	1.45	0.023	0.032	2.0	0.49	0.008
54 TI3	19.6	0.3	4.3	1.15	0.025	0.016	0.8	1.06	0.005

TABLE 3: *The Composition of the Test samples (contin.)*

*Sample Cat. no.	Percentage Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
55 TI4	18.5	0.4	4.6	1.15	0.028	0.018	0.8	1.50	0.008
56 TI5	21.4	1.2	7.6	1.05	0.079	0.020	4.6	1.25	0.011
57 TI6	23.4	0.4	6.1	1.39	0.021	0.019	0.3	1.10	0.008
58 TI7	23.0	0.8	9.0	1.08	0.126	0.014	0.4	0.33	0.012
59 TI8	18.9	0.6	5.7	1.08	0.080	0.023	0.6	0.64	0.010
60 TI9	17.0	4.1	7.9	0.89	0.092	0.072	21.0	1.50	0.041
61 TI10	23.6	1.1	7.9	1.18	0.055	0.019	6.1	0.88	0.009
62 TI11	~25	0.5	8.2	1.45	0.036	0.025	1.0	0.74	0.008
63 TI12	~25	0.7	6.7	1.45	0.031	0.024	0.3	0.56	0.010
64 TI13	24.6	1.2	9.3	1.23	0.072	0.022	7.6	1.10	0.011
65 TI14	24.5	0.4	4.6	1.27	0.031	0.017	0.9	1.05	0.006
66 TI15	24.6	0.9	7.9	0.92	0.095	0.018	0.3	1.35	0.011
67 TI16	16.2	1.0	6.1	0.91	0.086	0.016	3.4	2.15	0.011
68 TI17	20.5	0.9	10.5	0.99	0.260	0.013	6.9	1.10	0.010
69 TI18	16.0	1.9	6.5	0.82	0.089	0.021	10.0	3.20	0.016
70 TI19	22.3	0.8	8.1	0.85	0.141	0.010	0.3	1.70	0.011
71 TI20	23.5	0.8	4.3	1.25	0.032	0.018	0.6	0.74	0.008
72 KN1	18.5	5.0	8.8	0.84	0.058	0.058	15.5	0.93	0.053
73 KN2	14.9	5.6	8.8	0.85	0.080	0.052	8.7	1.42	0.051
74 KH1	13.4	4.3	12.5	0.68	0.084	0.022	1.8	0.56	0.020
75 KH2	14.2	4.5	11.0	0.86	0.099	0.065	9.0	1.40	0.043
76 KH3	19.1	0.6	3.8	1.23	0.037	0.027	0.3	0.68	0.007
77 KH4	12.7	0.8	6.8	0.80	0.073	0.020	5.5	0.83	0.010
78 KH5	10.5	0.8	6.3	0.78	0.038	0.023	1.6	0.46	0.014
79 KH6	16.0	0.8	7.7	1.05	0.065	0.026	1.8	1.75	0.012
80 KH7	18.2	0.9	8.0	0.92	0.038	0.034	8.6	0.68	0.017
81 KH8	15.0	0.2	3.5	0.98	0.047	0.014	0.9	0.49	0.006
82 KH9	9.0	0.4	6.4	0.75	0.092	0.019	1.2	0.51	0.010
83 KH10	10.8	0.6	6.8	0.80	0.072	0.024	4.5	0.52	0.009
84 KH11	12.0	0.9	5.7	0.80	0.074	0.019	3.4	0.70	0.009
85 KH12	14.3	0.7	5.8	0.89	0.068	0.015	2.5	0.66	0.010
86 KH13	18.2	1.8	8.1	1.07	0.075	0.033	5.8	0.49	0.036
87 KH14	12.8	1.5	9.4	0.83	0.048	0.031	5.6	0.90	0.013
88 KH15	15.7	1.6	6.8	0.81	0.071	0.030	6.4	0.87	0.018
89 KH16	14.7	0.7	7.8	1.00	0.065	0.031	8.2	0.62	0.008
90 TH43	14.0	3.5	7.5	0.69	0.076	0.041	7.7	1.40	0.025
91 TH44	22.5	6.1	9.0	0.89	0.097	0.046	17.8	1.75	0.038
92 TH45	17.0	8.8	10.8	1.08	0.117	0.099	16.0	2.60	0.058
93 TH46	18.8	4.9	8.3	0.91	0.097	0.042	12.5	1.20	0.033
94 TH47	21.5	8.4	9.7	1.04	0.120	0.053	27.5	1.30	0.048
95 MY8	24.6	0.5	6.7	0.95	0.028	0.013	12.9	0.92	0.008
96 MY9	17.7	4.9	8.3	0.75	0.075	0.048	11.2	0.24	0.039
97 MY10	17.7	3.8	9.4	0.79	0.106	0.045	18.1	1.12	0.036
98 MY11	20.1	1.7	7.9	0.82	0.047	0.031	16.8	0.72	0.015
99 MY12	15.5	5.6	7.5	0.85	0.069	0.050	7.1	0.68	0.035
100 MY13	16.6	0.6	6.8	0.74	0.041	0.012	0.3	0.98	0.006
101 MY14	19.0	0.6	7.5	0.75	0.095	0.014	0.3	1.11	0.006
102 MY15	21.6	0.7	7.2	0.85	0.107	0.015	0.3	1.08	0.008
103 MY16	20.5	0.6	7.4	0.84	0.107	0.014	0.4	1.22	0.007
104 MY17	17.0	4.5	6.7	0.84	0.067	0.040	9.0	1.07	0.029
105 MY18	24.5	0.8	9.0	0.89	0.094	0.017	0.4	0.98	0.009
106 MY19	21.0	5.9	10.0	1.03	0.088	0.052	11.4	0.69	0.042
107 SM1	16.0	0.7	5.4	0.92	0.135	0.010	0.2	1.60	0.014
108 SM2	16.1	0.5	4.5	0.93	0.151	0.010	0.3	1.25	0.006

TABLE 4. *Composition characteristics of the control groups*

Group	No. of samples	% of tot.		Percentage Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
Thebes	20	100	$\bar{x}$	18.7	5.4	9.0	0.88	0.101	0.058	14.3	1.30	0.053
			s.d.	2.7	1.8	1.6	0.12	0.024	0.025	3.9	0.45	0.026
Athens I	17	74	$\bar{x}$	16.8	4.9	8.7	0.85	0.086	0.090	15.0	0.94	0.051
			s.d.	3.3	1.0	0.8	0.10	0.013	0.017	6.8	0.36	0.008
Athens II	6	86	$\bar{x}$	14.9	3.5	8.2	0.80	0.073	0.073	4.2	1.39	0.041
			s.d.	1.9	0.4	0.5	0.66	0.009	0.007	1.4	0.41	0.005
Mycenae	19	100	$\bar{x}$	19.6	3.5	8.9	0.86	0.097	0.034	15.1	1.26	0.027
			s.d.	2.1	1.2	1.2	0.09	0.017	0.007	2.5	0.40	0.006
Knossos	24	100	$\bar{x}$	17.6	6.4	10.0	0.92	0.092	0.064	13.2	1.23	0.058
			s.d.	3.1	1.6	1.3	0.12	0.022	0.010	4.3	0.34	0.010
Palaikastro I	9	39	$\bar{x}$	19.7	1.5	6.1	0.84	0.048	0.022	1.5	0.89	0.012
			s.d.	2.8	0.3	0.7	0.09	0.009	0.011	0.8	0.29	0.006
Palaikastro II	10	43	$\bar{x}$	21.1	2.7	7.5	0.87	0.069	0.017	7.5	1.17	0.009
			s.d.	2.2	1.0	1.9	0.10	0.015	0.007	2.4	0.51	0.003
Chania I	10	100	$\bar{x}$	15.8	0.6	1.8	1.02	0.025	0.015	0.5	0.82	0.008
			s.d.	2.2	0.2	0.5	0.15	0.006	0.004	0.2	0.24	0.002
Chania II	9	100	$\bar{x}$	15.9	0.7	6.5	0.87	0.067	0.016	0.9	0.86	0.008
			s.d.	2.8	0.2	1.2	0.13	0.031	0.005	0.5	0.37	0.002
Chania III	14	100	$\bar{x}$	15.0	1.0	6.2	0.93	0.046	0.020	6.9	1.15	0.011
			s.d.	3.9	0.4	1.6	0.21	0.020	0.007	2.1	0.36	0.004
Chania IV	5	100	$\bar{x}$	17.9	2.0	6.8	0.74	0.076	0.020	11.6	1.13	0.014
			s.d.	1.6	0.7	1.3	0.04	0.026	0.004	2.6	0.40	0.005

$\bar{x}$ mean; s.d. standard deviation

TABLE 5: *Composition characteristics of groups of test samples on a site by site basis*

Group	No. of samples	% of tot.	Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
Thebes	14	$\bar{x}$	22.1	0.8	6.0	1.08	0.046	0.020	0.6	1.09	0.008
		s.d.	2.2	0.3	1.8	0.13	0.017	0.003	0.3	0.32	0.002
Thebes	18	$\bar{x}$	20.0	1.3	7.0	0.98	0.066	0.019	8.8	1.01	0.010
		s.d	3.5	0.5	1.0	0.14	0.012	0.005	2.7	0.39	0.003
Thebes	15	$\bar{x}$	18.9	5.8	8.6	0.97	0.099	0.061	15.1	1.51	0.041
		s.d.	2.6	1.9	0.9	0.17	0.023	0.023	4.6	0.45	0.010
Orchomenos	1		19.5	0.9	7.5	0.83	0.197	0.017	6.7	0.76	0.011
Eleusis	1		18.5	1.9	7.9	0.78	0.053	0.035	7.3	1.25	0.027
Mycenae	5	$\bar{x}$	20.4	0.7	7.6	0.81	0.081	0.014	0.3	1.07	0.007
		s.d.	2.9	0.1	0.8	0.07	0.031	0.002	0.05	0.10	0.001
Mycenae	3	$\bar{x}$	20.6	1.2	7.2	0.88	0.041	0.022	11.8	0.95	0.011
		s.d.	3.8	0.6	0.6	0.06	0.011	0.009	5.7	0.25	0.004
Mycenae	11	$\bar{x}$	17.3	4.3	8.3	0.81	0.084	0.047	13.7	0.99	0.035
		s.d.	2.3	1.0	1.2	0.09	0.013	0.009	4.3	0.46	0.005
Tiryns	11	$\bar{x}$	23.1	0.6	6.3	1.22	0.059	0.018	0.6	1.06	0.009
		s.d.	2.2	0.2	1.8	0.21	0.044	0.004	0.3	0.43	0.002
Tiryns	8	$\bar{x}$	21.6	1.1	7.5	1.10	0.063	0.020	6.0	1.40	0.011
		s.d.	4.3	0.4	1.8	0.24	0.026	0.006	2.6	0.87	0.003
Tiryns	1	$\bar{x}$	17.0	4.1	7.9	0.89	0.092	0.072	21.0	1.50	0.041
Knossos	2	$\bar{x}$	16.7	5.3	8.8	0.85	0.069	0.055	12.1	1.18	0.052
Chania	6	$\bar{x}$	14.0	0.6	5.6	0.95	0.058	0.021	1.4	0.76	0.010
		s.d.	3.7	0.2	1.6	0.18	0.021	0.006	0.8	0.49	0.003
Chania	7	$\bar{x}$	13.8	1.0	7.3	0.85	0.063	0.027	6.0	0.73	0.012
		s.d.	2.5	0.4	1.2	0.08	0.014	0.006	1.9	0.14	0.004
Sparta Menelaion	2	$\bar{x}$	16.1	0.6	5.0	0.93	0.143	0.010	0.3	1.43	0.010

$\bar{x}$ mean; s.d. standard deviation

TABLE 6. *Correlation of the test samples by visual assessment of the composition data*

	α West Cretan	β West Cretan	Probaby made locally at findspots	Uncertain
Thebes	1-4, 15-17, 21-23, 26, 29, 31, 38	5-10, 24, 25, 27, 28, 30, 32-34, 36, 37, 39, 40	11-14, 18-20, 35, 90-94	
Orchomenos		43		
Eleusis		44		
Mycenae	100-103, 105	45, 95, 98	46-51, 96, 97, 99, 104, 106	
Tiryns	54, 55, 57-59, 62, 63, 65, 66,	52, 53, 56, 61, 64, 67-69	60	
Knossos	70, 71		72, 73	
Chania	76, 78, 79, 81, 82, 85	77, 80, 83, 84, 87-89		74, 75, 86
Sparta Menelaion	107, 108			

statistical background, of the procedures employed, because a number of adequate accounts of their application to archaeological data of this type already exist elsewhere.[49] This is not to say, however, that the interpretation of the output from such techniques should not be tempered at all times by the judicious application of archaeological and chemical good sense: the goal, of course, is to derive from the mass of data groups of samples which are archaeologically interpretable and chemically meaningful, but which also satisfy a number of basic statistical requirements.

Some preliminary comments are appropriate on the form in which the data were used. It is the assumption of several of the most commonly used multivariate procedures that the data are normally, or near normally, distributed. Whether or not this is a reasonable assumption for a given data set must be evaluated empirically. As Wilson[50] noted, "a composition type is defined by a series of probability distributions, one for each of the measured elements [and] . . . the parameters defining these distributions have to be established in order to characterise the concentrations for a composition type." Recent studies have claimed strong support (without quoting relevant information) for the appropriateness of either the normal[51] or log-normal distribution;[52] but they have generally ignored the possibility that two or more different

[49] e.g. J. E. Doran and F. R. Hodson, *Mathematics and Computers in Archaeology* (1975); Wilson, *op. cit.* (*supra*, n. 29); A. J. N . W. Prag, *et al.*, *Archaeometry* xvi (1974) 153-88; M. Attas *et al.*, *Archaeometry* xix (1977) 33-43; N. Hammond *et al.*, *Archaeometry* xviii (1976) 147-68; Bieber *et al.*, *op. cit.* (*supra*, n. 32); Mertz *et al.*, *op. cit.* (*supra*, n. 32); G.K. Ward, *Archaeometry* xvi (1974) 41-53; F. Wideman *et al.*, *Archaeometry* xvii (1975) 45-59; G. de G. Sieveking *et al.*, *Archaeometry* xiv (1972) 151-76.

[50] Wilson, *op. cit.* (*supra*, n. 29).

[51] Catling, Richards and Blin-Stoyle, *op. cit.* (*supra*, n. 9); M. Picon *et al.*, *Archaeometry* xvii (1975) 191-99; cf. *supra*, n. 31.

[52] G. Harbottle *Archaeometry* xii (1970) 23-34; Bieber *et al.*, *op. cit.* (*supra*, n. 32); Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32) 164, n. 76.

composition types can occur amongst the samples from a single site. Moreover, although Harbottle[53] is probably correct in supposing that log-normal distributions provide the best description of natural impurities present at concentrations lower than Ca and Mg, this is a matter for statistical evaluation by formal tests for skewness and kurtosis which, unfortunately, require sample sizes larger than the maximum number of sherds assigned to a particular pottery composition in most previous studies of Aegean Late Bronze Age ceramics. In practice, we have found by extensive experimentation that where strong structure is latent in the composition data the form of the probability distributions employed has relatively little effect on the results obtained. The lack of firm conclusions in this area has dissuaded us from applying a uniform logarithmic transformation of the element concentration values. The data have, however, been routinely standardised,[54] since this is a widely accepted transformation which improves the characteristics of multivariate data by eliminating the bias of elements with large standard deviations, by narrowing the range of concentration levels of different elements, and by moving the distribution of data values for each element into closer conformity with that on a Normal curve. Some mention should be made also of the problems created by correlations between the concentrations of different elements.[55] Obviously, the stronger the correlation between any pair of elements *a* and *b*, the less value there is in measuring *b* as well as *a*, so that this question has some bearing on the vexed problem of the choice and number of elements to be measured. Table 7, computed from the full total of samples considered in the present study, indicates that significant correlations do indeed exist between c. 1/3 of the 36 pairs of elements.[56] The concentrations of Ni and Cr, Ni and Mg, and Mg and Cr, are a particularly strongly intercorrelated group; yet, as demonstrated below, each of these elements proved to be very useful in its own right in discriminating between pottery from different sites, so that we would clearly be acting prematurely to reject any element as wholly redundant. It is even less clear what impact such correlations have on the interpretation of results, particularly in terms of the assignment of samples to composition types. The lack of consideration of this problem is a deficiency in previous work, but further study of this effect is necessary before we know quite how to take it into account. Fortunately, the data transformations which form a routine part of certain multivariate techniques, such

TABLE 7: *Correlation coefficients for the 9 measured elements*[a]

	Al	Mg	Fe	Ti	Mn	Cr	Ca	Na	Ni
Al	—	−.003	.268	.479	.110	−.056	.242	−.151	−.069
Mg		—	$\underline{.609}$	−.060	.363	$\underline{.778}$	$\underline{.653}$	.261	$\underline{.867}$
Fe			—	−.062	$\underline{.587}$	$\underline{.566}$	$\underline{.586}$	.089	$\underline{.641}$
Ti				—	−.219	−.039	−.140	.027	−.073
Mn					—	.303	.484	.089	.402
Cr						—	$\underline{.523}$	.157	$\underline{.893}$
Ca							—	$\underline{.701}$	$\underline{.604}$
Na								—	.182
Ni									—

[a]Underlined coefficients are those greater than ± 0.5, the value corresponding approximately to the 0.05 probability level of significance.

[53] Harbottle, *op. cit.* (*supra*, n. 52).

[54] i.e. by subtracting from each case the mean values for each element and dividing by the standard deviation.

[55] cf Wilson, *op. cit.* (*supra*, n. 29) 223; Harbottle, *op. cit.* (*supra*, n. 52).

[56] i.e. 12 of the 36 pairs show a correlation coefficient higher than ± 0.5; this value corresponds approximately to a 0.05 significance level.

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as the discriminant analyses used in this study, eliminate the duplication involved with correlated attributes.

As with all studies of this kind, the first and crucial stages of data analysis must concern the identification of distinct pottery composition types among the samples of known provenance (ie the control samples). It is a legitimate criticism of much past work, as outlined above, that this has been attempted for samples of inadequate size and on a strictly univariate basis. Simple element-by-element inspection may in certain favourable cases allow a few composition types to be distinguished, even if individually they display quite large variability. However, the conclusion to be drawn from the cumulative results of the many hundreds of analyses by the OL & FL is surely that — for Aegean Late Bronze Age pottery, at least — there exists substantial marginal overlap between compositions and that certain clays from quite widely separated sites are not easily to be distinguished by examining each elemental concentration for each specimen in turn.[57] Multivariate procedures offer the obvious advantage of using the compositional data for all elements *simultaneously*, by regarding each case (ie individual pottery sample) as represented by a point in a space of *n* dimensions, whose axes measure the concentrations of each of the *n* elements. A distinct pottery composition should appear in such a hyperspace as a swarm or cluster of points, the density of points decreasing rapidly as the distance from the centre (or *centroid*) of the swarm increases. The likelihood of encountering a case from a given composition at a certain distance from the centroid is determined by the parameters defining the probability distributions of all the measured elements taken together (or the *joint probability distribution*), and it is of course on the basis of such likelihoods that we should decide whether or not a sample of unknown true provenance should be assigned to a given composition type. While there is no absolute guide to the sample size necessary to characterise the probability distributions of individual compositions, the number is certainly larger than the samples of single figure size which have been employed in the past.

For present purposes, however, the problem can be simplified somewhat. Although it is ultimately desirable to assign the ISJs to one or more well defined *clay composition types* related to identifiable local clay beds, the archaeological and historical interest of the material lies in the attempt to relate the ISJs to one or more *centres* at which they were manufactured and from which they were exported. If it proves possible to distinguish unambiguously (or at an acceptable level of confidence) between local pottery (ie control samples) from each of the *sites* under investigation, then this will serve as a satisfactory background against which to consider the likely provenance(s) of the ISJs, even if the control samples in fact contain more than a single composition type at each site. We have therefore focused our attention initially on the degree to which the control groups from each site taken as a whole can be clearly distinguished on the basis of elemental concentration data, rather than attempting to identify and define the composition types present at each site — a purpose for which our available data are probably not entirely adequate.

Multiple discriminant analysis offers the most effective approach to a problem of this type.[58]

[57] See, for example, Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32).

[58] Also referred to as *canonical variates analysis*. For other applications of this technique to Aegean ceramics, see Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32); Attas *et al.*, *op. cit.* (*supra*, n. 49); McArthur and McArthur, *op. cit.* (*supra*, n. 27). For details of the technique itself, see, for example, Doran and Hodson, *op. cit.* (*supra*, n. 49) 209-13; J.C. Davis, *Statistics and Data analysis in Geology* (1973) 442-56; also Wilson, *op. cit.* (*supra*, n. 29) 232-33. It should be noted that Euclidean distances in the transformed space created by multiple discriminant analysis corresponds to Mahalanobis D^2 distances in the original space, putting this technique in line with the distance measures advocated, for instance, by Bieber *et al.*, *op. cit.* (*supra*, n. 52) 67; Wilson, *op. cit.* (*supra*, n. 29) 232. The technique also eliminates the duplication involved with correlated elements noted above (p. 68).

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Briefly, the technique is designed for the situation where the cases are already divided into valid groups (here, the control samples from each site), and it attempts to weight and linearly combine the discriminating variables (here, the elemental concentrations) in a way that maximises the statistical separation of these prior groups. A series of discriminant functions is calculated in such a way that each successive function (or axis through the data) accounts for decreasing proportions of the separations between group centroids: this amounts to a transformation of the n-dimensional space defined by the original variables and their scores to a new space with the happy property that most of the total inter-group variance is often accounted for by the first few functions. Collapsing the multivariate data in this way allows group centroids and individual cases to be plotted on a two- or three-dimensional figure with minimal distortion of the original element concentration data, but which greatly clarifies the extent of the clustering or separation of the groups. Furthermore, it is possible (1) to evaluate statistically the success with which the discriminating elements actually can tell the groups apart, and (2) to identify which elements are the most, and which the least, helpful in this respect (and thus, in principle help eliminate the measurement of redundant or non-discriminating elements).[59]

A step-wise multiple discriminant analysis[60] was applied to the control samples, divided into 7 groups representing each of the sites at which they were found. Of the computed discriminant functions, the first three account cumulatively for 51.6, 75.8 and 91.7 per cent of the total variance between the groups, and thus subsequent functions can for all practical purposes be ignored. The combined set of functions resulted in 82.8% of the control samples being re-matched with their expected groups (ie assigned to their findspots), as below (Table 8). These results are, on the whole, very satisfactory and indicate that there is indeed a reasonably clear separation between site 'profiles'. While they imply that about 1 sample in 5 is 'misclassified', it is important to point out that the failure of certain sherds to be matched with their findspots may be due to shortcomings in the archaeological criteria used to select the samples rather than in the chemical and statistical procedures themselves; a low level of random error is to be expected in the latter in any case. The 'misclassifications' themselves are of no small interest. For example, the majority of the 14 samples from Thebes which were not assigned to Thebes were considered by the programme most likely to belong with the Knossos group, and 9 of them were in fact assigned to Thebes as the second most likely group; conversely, all 4 misclassified Knossos samples were confused with Thebes. This is a further indication of the substantial difficulties (p.53 above) encountered in distinguishing Theban from central Cretan compositions, largely because of the exceptionally variable concentration levels amongst the Theban control samples of Mg, Cr and Ni, (the elements which emerged as the most powerful discriminators in this analysis).[61] A low level of mutual misclassification likewise occurs between the Palaikastro and Chania[61 bis] control samples, but again this was fully expected on the basis of past work, and in every case the second most likely group membership proved to be the actual findspot. Of the five sherds of LM III brown ware from Chania, however, 4 were not assigned to Chania, and every other analysis shows this group of

[59] But Wilson, *op. cit.* (*supra*, n. 29) 233 quite rightly cautions against reaching such decisions too soon; as noted in this analysis and many others, elements useful or essential for defining some composition types may be of little value for others, and *vice versa*.

[60] In the step-wise method, the independent variables (elements) are selected for entry into the analysis sequentially on the basis of their discriminating power; the 'next best' discriminator is entered at each step.

[61] This problem is discussed further in the following section; it should be stressed, however, that the Knossos control itself *is* satisfactory, forming a reasonably tight and well separated cluster of points when plotted in the space defined by the first two discriminant functions.

[61 bis] Omitting from consideration the five sherds of Chania brown ware, as discussed below.

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TABLE 8: *Results of discriminant analysis on the control groups*

	Total no of samples	No. of samples assigned to their findspots	No. of samples 'misclassified'
Thebes	20	6	14
Athens	23	21	2
Mycenae	19	19	—
Sparta Menelaion	46	44	2
Knossos	24	20	4
Palaikastro	23	17	6
Chania:	48	41	7
(a) LMIII white ware	10	10	—
(b) LMI red ware	19	18	1
(c) LMIIIc ware	14	12	2
(d) LMIII brown ware	5	1	4

material to be anomalous. In the light of what has been said earlier, 5 sherds obviously provides too small a sample to define a discrete composition type, but it is nevertheless clear on the one hand that these samples are distinct from the remainder of the Chania controls, and on the other that their composition is reminiscent of Peloponnesian groups analysed earlier by the OL & FL. In view of this uncertainty, these samples have been omitted from further analyses.

These overlap problems, nevertheless, should not obscure the main conclusion, *viz* that multiple discriminant analysis provides a means of distinguishing the control material from the 7 sites, purely on the basis of the elemental concentration data, at a high level of reliability and significance. A visual representation of these results is provided in FIG 2. The 7 group centroids are plotted in the space defined by the first two discriminant functions, so that their separations give a minimally distorted view of the separation between the most typical case for each site; the circles enclose 90% of the cases from each site, indicating the spread of values around the site averages and thus the degree of overlap between groups. It becomes clear at once why it is difficult to distinguish from both east and west of the island. The discriminant function weights or coefficients produced as part of the output of the programme, together with the order in which variables were selected in the step-wise procedure, show which elements contribute most towards discrimination on these and subsequent axes: the separations achieved in FIG 2 are largely due to the influence of Ni, Cr, Al and Mg, in that order.[62]

Although this analysis achieved a good measure of discrimination between Palaikastro and Chania (74% and 85% correct classifications, respectively), it was decided to examine these two groups more directly. Their separation is, after all, a matter of crucial importance, since both sites have been claimed in the past as a likely source for the ISJs. The control samples were submitted to a two-group step-wise discriminant analysis in order to find the single linear function which maximises inter-group distinctions. A plot of the new scores for each case on

[62] These results may be compared with the discriminant analysis of McArthur and McArthur, *op. cit.* (*supra*, n. 27) 78; they were, of course, analysing wholly different samples (the 25 ISJs of C and M's 1965 analysis). On their single function accounting for 91% of the total variance, Mg, Ni, Ca, Cr and Fe achieved significance; in our analysis, Ca and Fe were ranked 6th and 9th in order of discriminating power.

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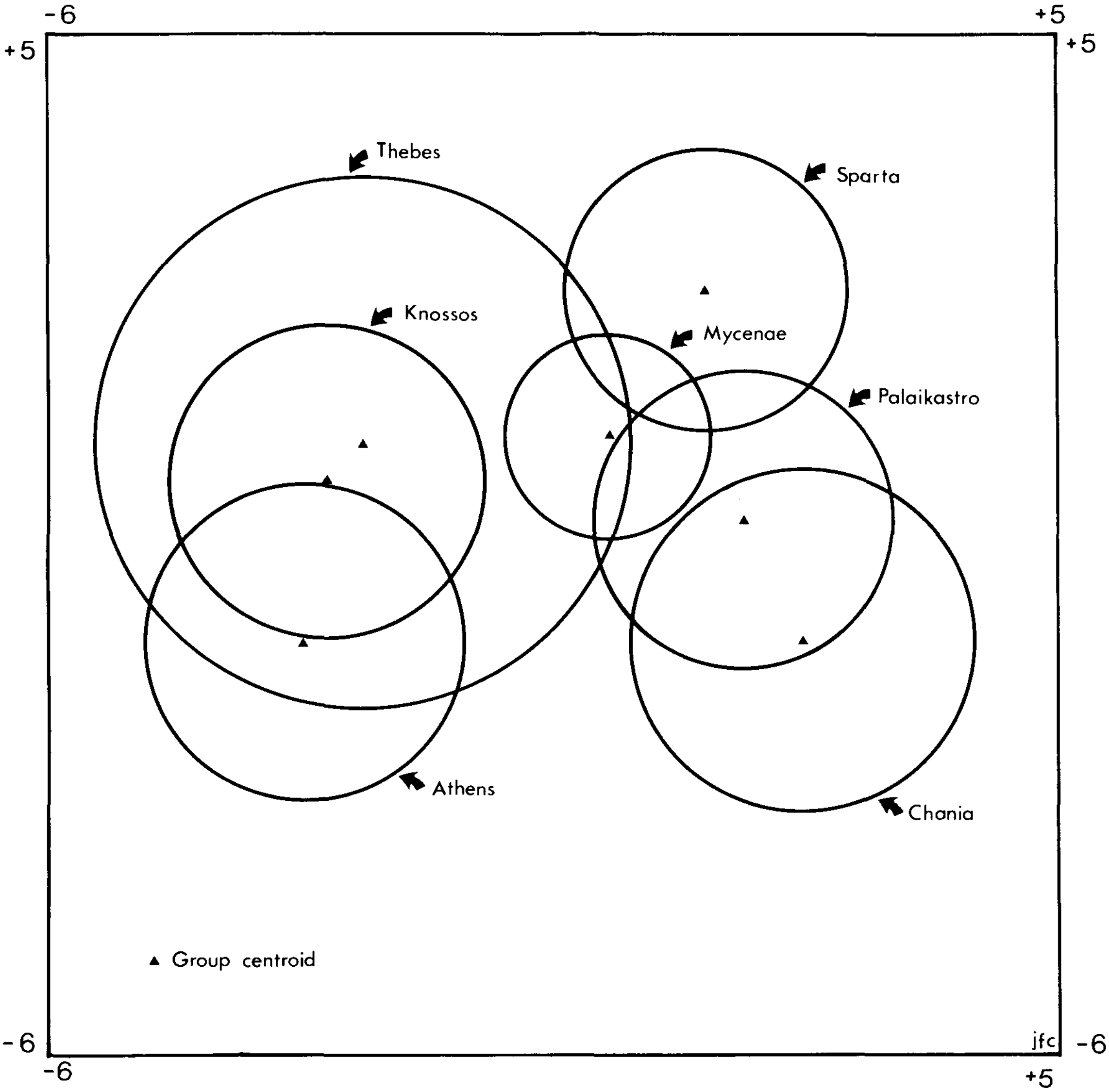

FIG. 2 Plot of the centroids of the control sample groups from each of the 7 sites in the space defined by the first two discriminant functions; the circles enclose 90% of the cases for each site.

the derived function (FIG 3) illustrates very clearly how satisfactorily it divides the Palaikastro material from the Chanis material: only two cases of the 76, one from either site, were not classified with their 'correct' fellows. All 9 elements entered this analysis as discriminating variables, but Mg, Al and Ti in this case contributed most to the discriminating power of the function. Furthermore, t-tests on each element to compare the mean concentrations of the two sample groups yielded values significant beyond the 0.01 probability level of significance for 6 of the 9 elements; this implies that there is indeed a true difference, in terms of concentration levels for most of the elements, between the two populations of pottery from which our samples were drawn.[63] Thus, although Palaikastro and Chania compositions are very similar when seen from the perspective of Aegean Late Bronze Age compositions as a whole (cf. FIG 2), they nevertheless *can* be separated at a high level of significance using the traditional suite of elemental measurements. In short, these results provide a reasonably reliable background for evaluating the assignment of the test samples to one or more of these possible production centres.

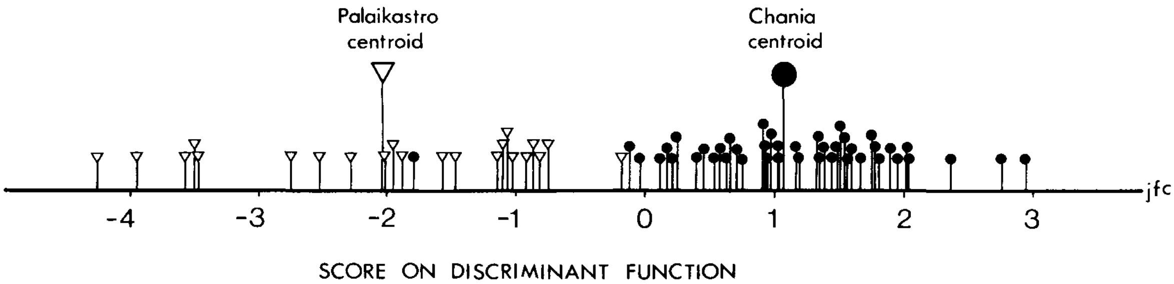

FIG. 3 Projection of control samples from Palaikastro and Chania projected onto the single discriminant function which yields maximum separation of the two groups.

Before turning to the ISJs themselves, it is worth remarking on the few modern clay/brick analyses and the extent to which their compositions match those of the ancient pottery for a given site. This question was examined by treating these samples as unassigned cases to be classified on the basis of their scores in the multiple discriminant analysis described above. The Tanagra brick sample was not assigned to its local Theban control, and compositionally it stands well apart, especially in its Al, Mg and Ca contents. The clay from Knossos is one sample among many that have been analysed from various locations in the vicinity of the Palace and it has been included in this study because it conforms more closely to the Knossos controls than any of the others; even so, it was not matched with its controls, probably because of the poor level of correspondence in Mg and Ni concentrations. In contrast, all the clays from the Mycenae region were attached to the Mycenae controls in the discriminant analysis. The Argos and Nauplion bricks satisfactorily match the control, apart from unusually high Mn[64] and (for Nauplion) rather low Al; the Berbati clay also fits, although the clay is more calcareous. Finally, the Ayia Marina clay (which was located after much searching, all the other clays in the area being highly calcareous; v. below) was matched, as hoped, with Chania. While it would be unwise to infer very much from this handful of samples, they do demonstrate nicely a more general finding that modern samples from non-calcareous clay beds tend to match local ancient pottery quite well, but calcareous clays—which are much commoner in the Aegean—suffer compositional dilution and distortion from the presence of free calcite, and rarely provide good matches (e.g. the Tanagra and Knossos specimens examined here). We discuss these geochemical problems further in the following section.

[63] t-test values significant beyond the 0.01 level were obtained for Al, Mg, Fe, Cr, Ca and Ni; those for Ti, Mn and Na had probability levels of 0.11, 0.13 and 0.43 respectively, and cannot be considered significant. The significance of the differences between the overall means for the two groups in n-dimensional space would, of course, have to be examined by a multivariate t test such as Hotelling's T (Davis, *op. cit.* (*supra*, n. 58) 433).

[64] Compositions of calcite tempered pottery from Neolithic Lerna have high Mn contents.

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The preceding analyses provide the indispensable background for the direct consideration of the stirrup jars themselves, to which we may now turn. Structure within the test sample data and the degree of fit with the control material were evaluated in 4 main ways: (a) principal components analysis, (b) hierarchical cluster analysis, (c) bivariate plots of the most powerful pairs of discriminating elements, and (d) classification of cases by their positions on the discriminant functions derived from the control samples, as described above.

Unlike the control samples, the findspots of the stirrup jars cannot be assumed to be reliable indicators of actual provenance: this, of course, is what the study aims to determine. They must therefore be treated as independent ungrouped cases within which latent structure is to be sought. Principal components analysis[65] offers a convenient inductive first-stage technique for this purpose, and the results of such an analysis on the stirrup jars are summarised in Table 9. An eigenvalue cut-off threshold of 1.0 yielded 3 significant uncorrelated components accounting cumulatively for 48.9%, 66.1% and 77.4% of the total variance in the data. The weights or loadings reported in Table 9 indicate the relative contribution of each attribute (element) to each of the new attributes (components or axes) and they allow the direct interpretation of the components.[66] Thus, principal component 1, accounting for almost half of the total variance, is related to the concentration levels of Cr, Ni and Mg in the original data; Al, and Ti dominate the second, less important, principal component; the third is accounted for by Mn and Na, but far less strongly. It should be noted that the relative importance of the elements suggested here corresponds exactly to their ranking in the discriminant analyses reported above. For each stirrup jar, it is possible to multiply its original (but standardised) concentration for each element by the appropriate component weight and sum these products to give a combined score for each case on each component. A scatter plot of the stirrup jar scores in the space defined by the first two components,[67] while useful as a visual representation of the degree of proximity or similarity between individual jars, failed to reveal any conspicuous clusters or divisions among the samples. As is commonly the case in multivariate data analysis, it is necessary to submit the data to alternative procedures and search for invariant structures in the ouput of *all* procedures.

Accordingly, the same set of data (ie elemental compositions for all the stirrup jars) was submitted to a hierarchical cluster analysis, using Ward's error-sum-of-squares method and a Euclidean distance measure. The resulting dendrogram, interpreted at the 4-group level, suggested a major split of the jars into two strongly dissimilar clusters.[68] The smaller of these is referred to here as cluster 1, whilst the larger cluster is weakly, and at a much later level of dissimilarity, divisible into 3 sub-groups, referred to here as clusters 2a-2c (Table 10). There are two interesting observations stemming from these results. Firstly, with the addition of **41** and **86** and the deletion of **36**, cluster 1 corresponds *exactly* to the 'residual' group of jars identified quite independently by purely visual inspection of the data (above, p. 63), and which it was suggested tentatively might represent jars made locally at their findspots; this in itself is a striking convergence of results. Secondly, the cluster output can be contoured onto

[65] Doran and Hodson, *op. cit.* (*supra*, n. 49) 190-7; Nie *et al.*, *op. cit.* (*supra*, n. 48) 468-514; S. Daultry, *Principal Components Analysis* (1976): Davis, *op. cit.* (*supra*, n. 58) 478-500; Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32) 164-65. It should be noted that the component weights reported in Table 9 are those on the *rotated* matrix, in order to enhance the interpretability of the components in terms of the input variables.

[66] The importance of the weights is expressed by the *absolute* values, not by whether they are positive or negative.

[67] cf. Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32) FIG. 6; The scatterplot is not reproduced in the present paper.

[68] These two clusters only fused at a dissimilarity coefficient level of c. 80, whereas all other point and cluster fusions occurred at levels of below c. 25. It should be noted that the choice of the number of groups regarded as significant is a largely subjective decision reached on the basis of the overall morphology of the dendrogram.

TABLE 9: *Results of a principal components analysis on the ISJs and SJs*

	Principal Component 1	Principal Component 2	Principal Component 3
Loadings on rotated principal component matrix:			
Al	−0.157	0.862	0.172
Mg	0.895	−0.089	0.350
Fe	0.490	−0.274	0.569
Ti	−0.081	0.882	−0.250
Mn	0.280	−0.358	0.734
Cr	0.941	0.012	0.008
Ca	0.730	−0.226	0.216
Na	0.105	0.242	0.701
Ni	0.922	−0.145	0.243
Eigenvalue	4.399	1.547	1.020
% of variance explained	48.9	17.2	11.3
Cumulative % of variance explained	48.9	66.1	77.4

TABLE 10. *Results of hierarchical cluster analysis of the ISJs and SJs*

	Cluster 1	Cluster 2a	Cluster 2b	Cluster 2c
Thebes	**11-14, 18-20, 35, 36, 42-47**	**3, 16, 17, 21-24, 26, 39**	**6, 8, 10, 15, 33**	**1, 2, 4, 5, 7, 9, 25, 27-32, 34, 37, 38, 40, 41**
Orchomenos				**43**
Eleusis				**44**
Mycenae	**46-51, 96, 97, 99, 104, 106**		**45, 100**	**95, 98, 101-103, 105**
Tiryns	**60**	**53-55, 57, 59, 62, 63, 65, 71**		**52, 56, 58, 61, 64, 66-70**
Knossos	**72, 73**			
Chania	**74, 75,**	**76, 81,**	**77, 78, 82-85, 87-89**	**79, 80, 86**

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the scatter plot of principal component scores in order both to emphasise the underlying structure of the plot and to aid the interpretation of the clusters themselves.[69] The stirrup jars in cluster 1 proved to be those on the extreme right of the plot (ie scoring positively on the first principal component), while clusters 2a, 2b and 2c corresponded to positive, negative and neutral scores on the second principal component. In other words, the distinction between clusters 1 and 2, and between clusters 2a, 2b and 2c can be interpreted fairly directly in terms of the elements loading strongly on principal components 1 and 2, respectively.

The separation of the jars of cluster 1 and the remainder was investigated further in a more intuitively obvious way by simple bivariate plots of the raw scores for each case on each of the most discriminating elements. It emerged quite clearly in all the foregoing analyses that Ni, Cr, Mg and Al are the most useful elements in this respect. FIG 4, therefore, shows the scatterplot of raw scores for Ni *vs* Cr; the linear structure of the data points is due, of course, to the very strong positive correlation between these two elements discussed above (cf Table 7). Once again, an exact separation emerged between jars in cluster 1 (points denoted by symbols) and those in cluster 2 (points falling within shaded zone, not marked individually). The ISJ from Eleusis is the only sample classified in cluster 2 which did not fall within the shaded zone, although it is the closest of all the points outside the zone.[70] The crucial observation, however, is that the shaded zone also *encloses ALL the Chania control samples* and *excludes ALL the control samples from other sites*, except Palaikastro which, while overlapping substantially, extends beyond the upper range of the Chania values for Cr and Ni. In other words, the majority of the jars (cluster 2) are to be associated *exclusively* with the Chania (and, less strongly, the Palaikastro) controls, and the remainder *exclusively* with the control samples from the Mainland and Knossos.

As a final step, we may check these important conclusions by returning to the discriminant functions derived earlier from the control samples with known group membership, and by using these predictively to classify the jars into their most likely groups. Caution is necessary, however, because the programme is forced to assign cases to the most likely of the pre-specified groups, even if none of these groups in fact provides a good match; consequently, it is prudent in the first instance to consider only whether or not a jar is classified with the controls from its findspot. Seen in this light, the discriminant function classification of the jars offers a strong, though not perfect, measure of support for the conclusions reached above. **44, 43** and **107** and **108** are not classified with their controls, but assigned to Chania. For Tiryns, **60** and **69** are considered to be local and 15 of the remaining 18 are assigned to Chania. Both ISJs from Knossos are matched with the Knossos controls; similarly, all Chania ISJs are locally matched, except **72** and **73** which are perhaps best regarded as unclassified. The results for Mycenae correspond to expectation less well, and for reasons that are not clear: **46 – 48, 51, 97** and **98** are considered local; **45, 95** and **100 – 104** from Chania; the remainder assigned to other Mainland sites. Finally, it might be expected that the Theban jars would classify inconsistently, since their own controls are poorly defined and overlap substantially with other sites (above, p. 53 and p. 57). In the event, however, 21 were assigned to Chania, 8 to Palaikastro (probably in error for Chania), and the remainder to Mainland centres, dominantly Thebes itself. With the exception of numbers **5, 34, 36** and **39**, the Theban test samples are thus divided between local (Mainland) and imported (Cretan) in exactly the same way as suggested by preceding analyses.

[69] cf. Cherry and R. Hodges, *Antiquaries Journal* lviii (1978) 299-309, FIG. 4; Hammond *et al.*, *op. cit.* (*supra*, n. 49) FIG. 4.

[70] See below, p. 81.

[71] *vacat.*

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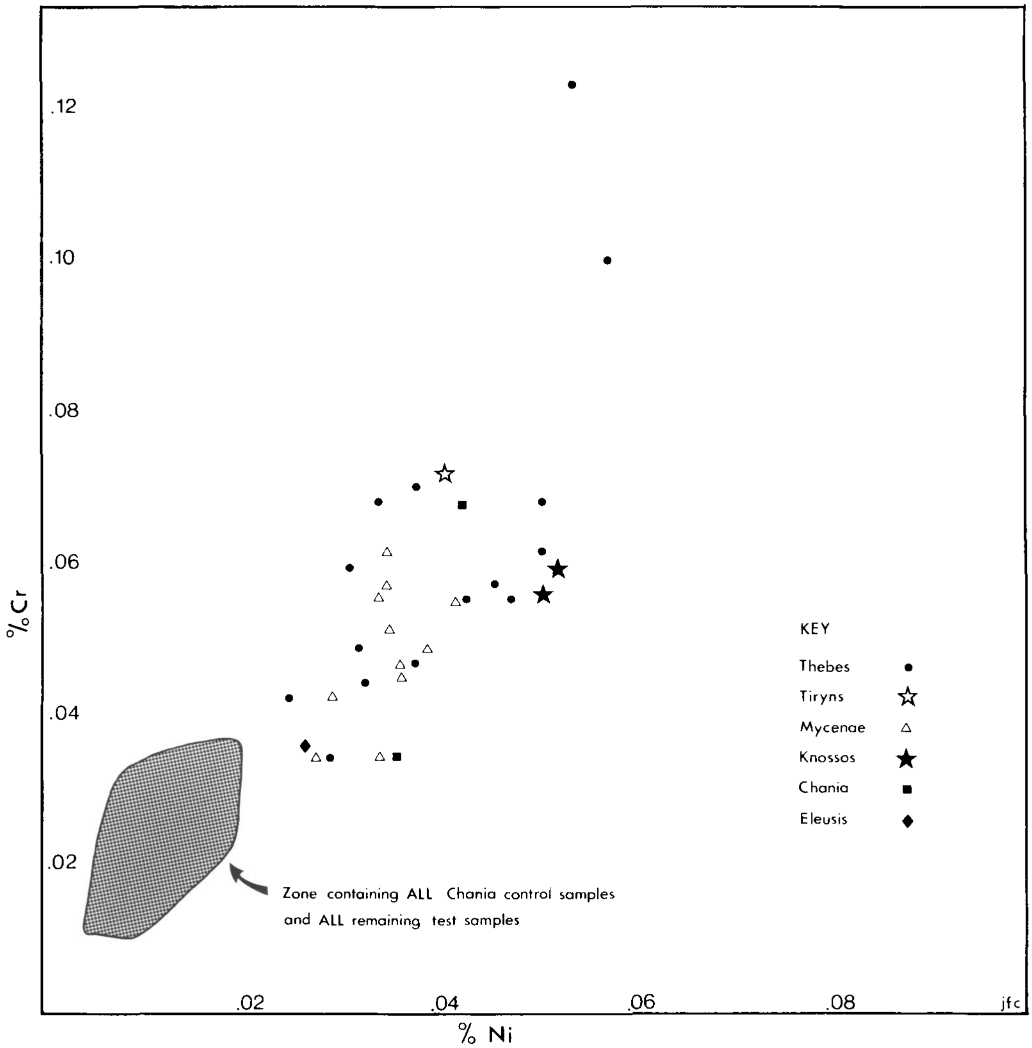

FIG. 4 Bivariate scatterplot of raw scores for nickel and chromium concentrations in the test samples.

We therefore feel it is legitimate to conclude from the convergent results of the several multivariate and univariate analyses discussed in this section that the majority of the 108 jars considered here were produced in, or very near, Chania. Such a conclusion should probably be expressed in a less determinate form: that the compositions of these jars match the compositions of local Late Bronze Age pottery from Chania much more closely than any of the other sites where inscribed stirrup jars have been found, and that Chania is therefore the most likely source among the sites considered in the study.

It remains to consider briefly the question of variability *within* this larger group of Chaniote jars. The hierarchical cluster analysis (Table 10), and to a lesser extent the principal components analysis, suggested 3 sub-groups within this material, principally reflecting variation in Al and Ti concentration levels. Inspection of the data also suggests important variation in Ca (cf Table 9, Ca loading on first principal component) and it was on this basis that two groups termed α and β were provisionally suggested (above, p. 63). As a purely heuristic exercise, a 2-way step-wise discriminant analysis was performed using α (39 cases) and β (34 cases) as the two pre-defined groups to be statistically separated. The positions of the jars in each group on the single discriminant function are plotted in FIG 5. It is obvious that although β group is more variable than α there is an excellent degree of separation: 96% of the cases were 'correctly' classified, only **53**, **24** and **36** falling in α rather than β group, as predicted. Discrimination on this function is dominantly related to concentration levels of calcium and aluminium, suggesting that at least two clay compositions may be present among the jars attributed to Chania, one calcareous and one non-calcareous. The geochemistry of the Chania claybeds is discussed further in the following section. However, it is apparent that a less speculative definition of the various composition types present will necessitate a larger programme of sampling and analysis of the local Late Bronze Age pottery of Chania and western Crete. The progress that has already been made in this direction is also reported in the next section. The accumulation of such data may clarify, especially, the significance of the result for the Eleusis jar.

On the one hand, its composition can be demonstrated to be close to, but not identical with, that of the Chania controls and jars; on the other, it has become clear from recent philological work that *da-*22-to* is not to be considered a member of the West Cretan *ku-do-ni-ja/a-pa-ta-wa* group of toponyms, but rather is associated with the *da-wo/pa-i-to*[72] group and probably lies to the west of Tylissos. These two facts may not be unrelated. **44** may therefore represent an example of a composition from some location *between* Knossos/Tylissos and Chania, though whether it reached Eleusis directly or was shipped via Chania is obviously an unanswerable question.

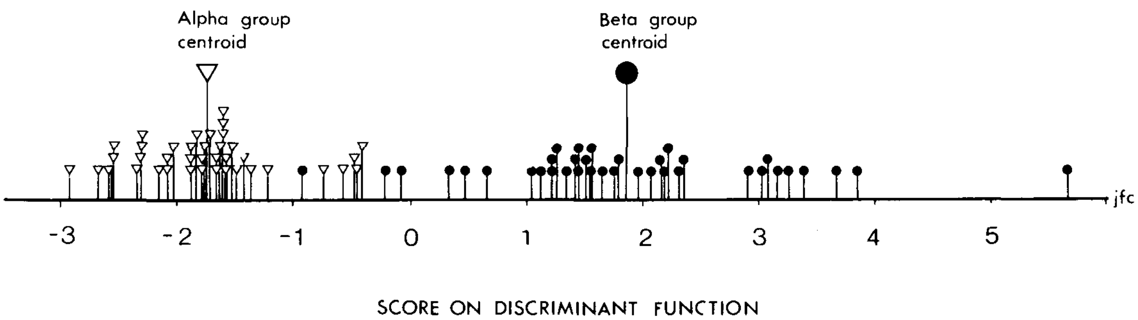

FIG. 5 Projection of test samples from α and β groups projected onto the single discriminant function which yields maximum separation of the two groups.

Summary. The following are the most important substantive conclusions to emerge clearly from the rather complex analyses discussed above:

1) Multivariate procedures, especially multiple discriminant analysis, allow the 7 sites considered in this analysis to be distinguished at a high level of confidence on the basis of elemental concentration levels in small, semi-random samples of local pottery. Theban compositions, however, remain unsatisfactorily characterised on account of unusual variability in Cr, Ni and Mg, and there is systematic mutual misclassification of Theban and central

[72] This is Group I in the most recent and exhaustive study of Wilson, *op. cit.* (*supra*, n. 20) 88-91 and 102.

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Cretan samples. Both larger sample sizes and supplementary analyses by neutron activation and petrographic methods are desirable to clarify the problem.[73]

2) It is possible to derive from the elemental concentrations in local pottery from Palaikastro and Chania a discriminant function that distinguishes between these two compositionally similar sites with a 97% success rate.

3) The convergent results of several multivariate analyses indicate that the 108 stirrup jars sampled in this study fall into two main groups; the larger of these is comprised of jars likely to have been made at, or very near, Chania, while the small group consists of jars probably made locally at their findspots. The position is summarised in Table 11.

4) There is some evidence for the presence of several compositional types amongst the Chania control samples and the ISJs assigned to Chania. The most important axis of variability may be the division into calcareous and non-calcareous clay compositions.

5) The elements Cr, Ni, Mg, Al, and Ca are the most powerful discriminators for this set of data; the remainder play little part.

TABLE 11. *Suggested provenances of the inscribed and uninscribed stirrup jars considered in this study*

	Probaby made *at* or near Chania	Probably made locally	Between Knossos & Chania?	Uncertain[74]
Thebes	All other Theban samples	11-14, 18-20, 35, 41-42		36
Orchomenos	43			
Eleusis			44	
Mycenae	All other Mycenae samples	46-51, 96, 97, 99, 104, 106		
Tiryns	All but 60 and 69	60		69
Knossos		72, 73		
Chania	76-85, 87-89			74, 75, 86
Sparta Menelaion	107, 108			

Discussion. The aims of this analytical study, which has a sound archaeological basis, has been to determine the origins of a large proportion of the ISJs found at five Mainland and two Cretan sites and of a number of uninscribed jars from four Mainland sites. The work represents the most ambitious of its kind to date on Aegean material, and its aim has been achieved to a considerable extent. This has lain partly in the adequate level of sampling from the statistical point of view (108 test and 226 control samples); it may also be attributed to the fortunate distinction which exists between the pottery compositions of the Mainland sites and

[73] A point stressed recently by Fossey, *op. cit.* (*supra*, n. 36)

[74] The designation of samples to the category 'Uncertain' in Table 11 implies that they have *not* been satisfactorily assigned to any of the control sites considered in this study.

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those of the suggested origin of the majority of the test material—Chania. Several points, however, arising directly out of the results presented in the previous section require clarification and comment. These form the substance of this discussion, but there are other issues of a more general nature relating to the laboratory's composition and provenance studies which it has been thought desirable to include.

We may begin with an appraisal of the confidence with which Chania (or its close vicinity) has been classed as a major production centre of the jars. How typical are the Chania clays of west Crete as a region, and how do they compare with those of the island as a whole? The visual representation of the results for the control sites in FIG 2 indicate that Knossian compositions are readily distinguishable from those at Palaikastro and Chania. These three sites can in fact be classed as markers for what have been identified as three composition zones on Crete. This finding has been based on the analyses of pottery from some twenty Minoan sites throughout the island, some of which are marked on the map in FIG 6. The east Cretan compositions have been limited in extent to those encountered at Palaikastro, Zakro and Piskokephalo. At the former site, the complexity of composition types derived from C and M's analyses has been somewhat simplified by the present results. Two main groups, accounting for 19 of the 23 samples, have been identified, from the visual classification (see Table 6) and they are distinguished from each other by their Ca contents. They conform broadly with Millett's Types O and G. The remaining four samples have variable compositions, none of them central Cretan in character, and they are most likely to be local, but minor variants. The central Cretan compositions, exemplified by those at Knossos, extend at least to Gournia and Pseira in the east, along the south coast (Myrtos (Fournou Koriphi) and Pyrgos) as far as Kommos, through the Mesara plain (Phaistos and Agia Triadha) and to Tylissos in the north west. The central Cretan clays are more calcareous than those in the east and west of the island, and they exhibit some diversity of compositions with respect to Mg, Cr and Ni contents. The extent of this heterogeneity of compositions varies among the sites, and, for example, at Knossos it appears to change chronologically. Sixteen LM IB cups of fine fabric were selected as a Knossos control in the provenance study of Marine Style;[75] ironically, they showed a greater spread of compo-

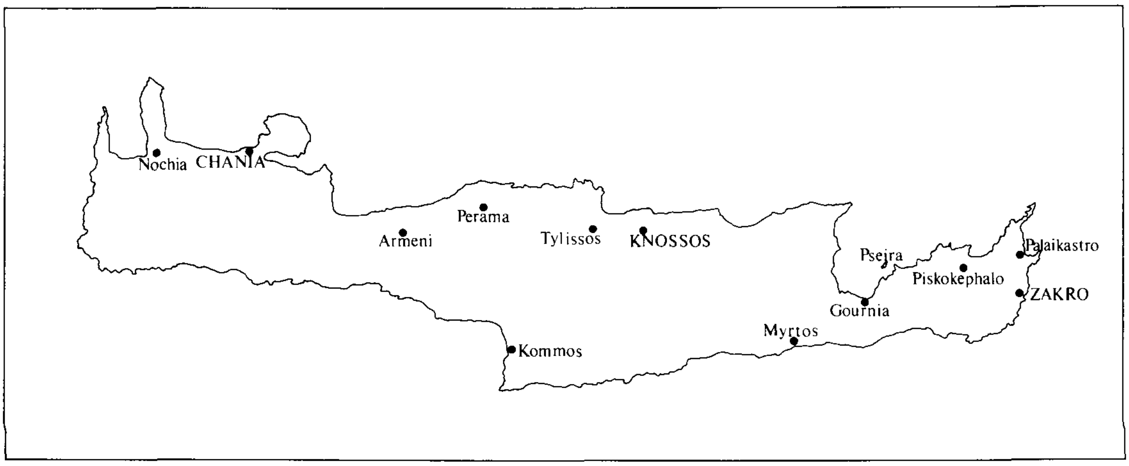

FIG. 6 Map of Crete showing some of the sites for which composition data have been obtained.

[75] Mountjoy, Jones and Cherry, *op. cit.* (*supra*, n. 32).

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sitions than did the Knossian material analysed in this study which covered a range of fabrics.

By contrast with the compositions of the east of the island, those of the west are quite widely distributed geographically. At Nochia the compositions of twenty plain ware samples divide themselves unequally between two groups which closely resemble Chania II and III. At Armeni, Pygi[76] and Perama the compositions include a number which are evidently central Cretan in character; the majority, having low Ca contents, conform in outline to the Chania pattern, but there are nevertheless some discernible differences. It is this feature which encourages us in our belief that the Eleusis jar, as we have already noted, in having a composition which stands slightly apart from those of Chania, may originate to the east of Chania while still probably west Cretan. This tentative assignment of provenance will, it is stressed, remain unsubstantiated until more data become available for Armeni and until the region has been throughly surveyed analytically.

For Chania itself, it remains to discuss the site's exceptional pottery compositions which were first commented upon by C and J and by Asaro and Perlman (but without supporting data).[77] The analytical data (Table 4) suggest that Chania I, II and III represent distinctive, but all local, clays; this statement is based upon the fact that they appear on initial inspection to be related by the following sequential scheme:

$$\text{Chania I} \xrightarrow{\quad\text{Fe}\quad} \text{Chania II} \xrightarrow{\quad\text{Ca}\quad} \text{Chania III}$$

There are two possible lines of explanation of this phenomenon, unique so far in the Aegean: the three groups are either represented by three locationally separate claybeds formed under differing geological conditions, or by a single large, but heterogeneous, clay bed. There are two persuasive arguments in favour of the former explanation. Firstly, the fabrics of the wares belonging to the three composition groups differ markedly: the white ware (Chania I) is fine with occasional small dark inclusions, the colour varying from white 10YR/8/2 to a very pale brown 10YR/8/3; Chania II is typified by conical cups in a light red rather coarse fabric (2.5YR/6/8) with occasional large white inclusions and several smaller but well distributed inclusions; it is also represented by the finer red undecorated and white slipped wares; Chania III is represented by the LM IIIC ware of light red colour (generally 2.5YR/6/8), the quality of whose fabric is intermediate between those of the white ware and light red cups, and also by the red decorated ware.[78] Secondly, the clays, whose compositions match the Chania II and III groups, have been successfully located at Ayia Marina. The sources of the modern red and grey clay deposits, although in close proximity, are physically distinct. The geology of the region consists of a narrow coastal band of alluvium, on which Ayia Marina lies, and this runs eastwards and just to the south of Chania towards Souda Bay. Tertiary marls encroach immediately upon the alluvium, a feature which largely accounts for the failure to locate a non-calcareous white clay in west Crete. Chania IV, which arguably might be thought of as the next step in the above sequence: Chania III $\xrightarrow{\text{Mg}}$ Chania IV, is on balance more likely to be an imported group (see p. 70-71). It has a fine fabric with occasional small white inclusions, the colour ranging from reddish yellow (5YR/6/6) to yellowish red (7.5YR/6/6); the composition resembles those of Kythera and parts of the (south) Peloponnese.

[76] The samples from the Armeni and Pygi cemeteries were kindly provided by Mr. Y. Tzedakis.

[77] F. Asaro and I. Perlman, *Acts of the International Symposium 'The Mycenaeans in the Eastern Mediterranean*, Nicosia (1973) 213-24.

[78] A distinction must be made between these fabrics and another probably local ware of the LM III period. This has a granular fabric with small black grits, the colour ranging from light grey (5YR/7/2) to light olive grey (5Y/6/2). The chemical composition of this ware has not yet been determined.

We may take note at this stage of the reason why C and M were able to match the Theban ISJs with the east Cretan centres. The clays of the eastern and western ends of the island are compositionally quite similar; not only is there diversity of clay types (in simple terms, a division between calcareous and non calcareous clays), but the concentration ranges of their compositions overlap such that a differentiation between the sites is only accomplished with difficulty and by recourse to the sophisticated means of data analysis adopted here. Given that the 'pottery map' of the Aegean has been extensively enlarged since C and M's study (about fifty Late Bronze Age sites have now been at least partially characterised) it may be asked whether there are any sites or regions in the Aegean, other than west (or east) Crete, which may be matched with the two classes of jars α and β. The answer is unequivocal: there are none which can accommodate *both* classes α and β. The distribution of the jars, inscribed and uninscribed, between the two classes merits further attention. A remarkable aspect of the results for the imported ISJs from Thebes and Tiryns and the locally made ISJs from Chania is the tendency towards their equal representation in classes α and β (Table 6 gives the numbers). The Mycenae imported ISJs themselves differ in this respect, but when they are considered in conjunction with the imported *un*inscribed jars the picture returns to that for the other sites. We should bear in mind, however, that the distinction between classes α and β was derived from the univariate analysis of the data, and it was based on the Ca contents. The validity of this judgement should be tempered by the results of the hierarchical cluster analysis which indicated that the distinction, although dominated by Ca, was more realistically accounted for by a combination of elements including Al. The wide variation in the contents of this element was an unexpected result of the compositions of the test material as a whole; Al was found in unusually high concentration in the Tiryns group. The causes of this effect cannot be readily explained in terms of any physical properties which are peculiar to the jars alone, but it should be remembered that after Cr, Al is the next most poorly reproduced element. The Al spectral line at 2575 Å is particularly susceptible to emulsion properties and developing conditions.

Another observation is the presence in class α of all the light on dark examples (forming 10% of the total analysed assemblage of SJs) with the exception of **37**, a logical consequence of which is that classes α and ß should represent the exploitation of two distinct clays at one or more production centres. There is a strong case in favour of the existence of more than one production centre for the jars since the use of the two clays at one centre alone would most likely have led to occasional mixing of clay batches. In turn, this would result in a change from the two observed and separated Ca distributions of α and β to one broad Ca distribution. If there were at least two centres, what can we say about them? Firstly, they may both be attributed to Chania itself owing to their close matching with the local pottery fabrics. The jars, as has already been noted, have a coarse fabric as befits large storage/transport vessels; that they were deliberately tempered appears likely in view of the relative size and variability of their inclusions as compared with those in the fabrics of Chania II and III wares. There seems to be no good reason to suppose that the clays employed for preparing the jars were specially selected — the potters used the same clays for the jars as for the rest of their ceramic output, but the production of the jars necessitated and addition of temper to clay. Alternatively, as the compositions of the clay material from Ayia Marina[79] have shown, the workshops could have operated separately in the vicinity of Chania. Whatever their relative geographical location was, the evidence points towards a degree of independence on their part, and yet they appear to have been equally committed or involved in the export market. Secondly, at least one workshop practised the production of jars of the type we have just noted, which were fired,

[79] Only the compositions of the grey clay has been included in the multivariate analysis.

certainly in the final stage, in a heavily reducing atmosphere. They were prepared from a non-calcareous clay in contrast to a majority of the jars with dark on light decoration which were prepared from a calcareous clay (class β), and were fired under oxidising conditions. This contrast is significant since it presupposes an understanding on the part of the potters of the suitability of clays to particular firing conditions. It is known that a reducing atmosphere in the kiln causes more vitrification at 800°C in a non-calcareous clay than in a calcareous clay. Higher temperatures are required to ensure the same level of vitrification in a calcareous clay.[80] At the lower end of the firing range (800-1050°C), this will result in the body of the light on dark jars being less porous than that of the dark on light jars. On the other hand, a reason has then to be advanced to explain the preponderance of the latter class of jars; this may lie in the fact that the jars prepared from a calcareous clay are easier to fire. They require less rigorous control of the temperature during firing in order to achieve extensive vitrification consistent with a strong, non-porous body.

Moving to the groups of test material attributed in Table 11 to their findspots, further mention must be made of the inability to distinguish between the Thebes and Knossos compositions. The wide concentration ranges for Mg, Cr and Ni in the Thebes control largely account for the size of the Thebes 'circle', which wholly encompasses that of Knossos, as demonstrated visually in FIG 2. The cumulative evidence gained from the analyses of Mycenaean pottery from several sites in Boeotia strongly suggests that this phenomenon is inherent in the pottery of this region.[81] Consequently, there is no reason to doubt the attribution of the Thebes control, which was based on archaeological good sense, as local products. Regrettably, no convincing explanation of this Thebes-Knossos 'effect', which has had repercussions beyond the present study,[82] is yet forthcoming, although the presence of serpentinised ophiolites in the shale-sandstone-chert formation in the hills to the north and north east of Thebes may be relevant in this connection. It is hoped that when sufficient petrological data become available for a chronological sequence of pottery from the two sites the situation may be clarified.[83] For the time being, the sites remain indistinguishable, and thus a more realistic assignment of the provenance of the 'probably local' group at Thebes is *Thebes-Knossos*. This is an appropriate place to point out that, among the ISJs from Thebes, which were not reanalysed by C and J, **13** (C and M 20) and **25** (C and M 24) were resampled in this study. **13** falls into the Thebes-Knossos group, and **25** is a member of the imported class β, a result which is more in keeping with McArthur and McArthur's findings.[84] Gratifyingly, but not unexpectedly, the other resampled ISJs from Thebes (**2**–**4**, **6**, **8**, **9**, **15** and **16**) divide themselves between classes α and β in the same way as they were assigned by Millett to her groups 1-12 and 13-18. There are also the analyses of ISJs TH Z 943 and TH Z 944 (C and M 22 and 23), whose compositions were given in n.34, to consider. These compositions fall within the Thebes control ranges, and thus they may tentatively be assigned to the Thebes-Knossos group. The corresponding 'probably local' groups at Mycenae and Tiryns should be more secure, but it may be noted that Mycenae **104** and **106** are in their Mg and Cr contents somewhat atypical of the Mycenae control compositions; they tend towards the lower limits of the Knossos ranges. The Knossos vases, **72** and **73**, although notably different in their fabric, have similar compositions and are in all likelihood local.

80 Y. Maniatis and M. S. Tite, *Thera and the Aegean World* I (London, 1978) 483-92.

81 The initial survey made by C and M included the following sites: Thebes, Orchomenos, Gla, Kalami, Eutresis, Pyrghos and Arma. More recent analytical work has been conducted by Miss S. White on material from: Dramesi, Chalia, Kynos, Anthedon and Arma.

82 R. E. Jones & C. B. Mee, *Journal of Field Archaeology*, v (1978) 471-482.

83 Work of this kind is currently being carried out by Dr. J. Riley at Southampton University.

84 See p. 56.

Two comments about the control material, in addition to those already discussed, need to be made:

1. *Unequal sample sizes among the site controls.* Mycenae, for example, is represented by only 19 samples in comparison to 49 for Chania. The FL has 70 control samples, mostly from fine ware, for Mycenae covering the periods LH I/II to LH IIIC; only small variations in composition are observed over this 400 year period, and in consequence it was decided to restrict the Mycenae control to the relevant period, LH IIIB. To the FL, the Mycenae group is a good example of a multi-purpose control which has been utilised to good effect in many of the laboratory's provenance studies. By contrast, in the absence in the FL's data bank of a good chronologically defined control accounting for a range of fabrics, the Palaikastro group was specifically prepared for this study.

2. *Bias towards fine wares in some of the site controls* (Thebes, Mycenae and Sparta Menelaion). Although the designation of category fabrics into fine, semi-coarse and coarse is inevitably subjective, there is evidence from other studies of the FL and OL, and from the present Knossos and Palaikastro controls, that with adequate sampling weights (see sampling section above) many of the coarser fabrics have similar or overlapping compositions with those of the fine wares. Among the exceptions, none of which is relevant to the present study, are calcite and serpentine tempered wares and domestic cooking wares whose necessary high quartz content effectively dilutes the clay component composition.[85]

Finally, there are some issues which are relevant not only to this study, but more generally to composition and provenance investigations. Attention must initially be drawn to the fact that the present data have all been obtained in the FL over the last four years, there being no attempt to incorporate directly the OL's old data on similar or parallel material derived by the same technique. In 1971 the OL changed the original calibrations from which the elemental contents were determined. This change, of which McArthur seemed to be unaware,[86] was necessitated by the decision to base the calibration on USGS rock standards rather than on pottery standards; the results were published in full by Schweizer.[87] Conversion factors, by which old (pre 1971) data could be corrected to a form consistent with the new calibrations were given;[88] these factors varied from element to element, the Ca content, for example, remaining unaltered, the Cr content requiring multiplication by 0.5. No further changes have since been made to the calibrations, and both the OL (until 1976 when it discontinued the spectrographic technique) and the FL (since 1974) have continued to use USGS rocks as the primary standards. But there are, however, three factors, which in the light of present evidence, prevent the FL from directly incorporating old (pre 1971) data into its own studies: firstly, the realisation that the published correction factors are inoperable over a wide concentration range; there is an optimal range over which they apply and may be used with impunity.[89] Strict conversion from the old calibration to the new one requires a 'sliding scale' factor, the determination and manipulation of which would require computer facilities. Secondly, OES, in its application to archaeological material, has not remained a static technique; modifications and improvements have inevitably been introduced. One effect of this situation, coupled with the inherent limitations of the technique as regards the errors involved in the elemental content determinations, has led to an inability to maintain fully the reproducibility of composition data over a fifteen or even a ten year period. Thirdly, and this

[85] R. E. Jones, *Thera and the Aegean World* I (London 1978) 471-82.

[86] McArthur, *op. cit.* (*supra*, n. 35).

[87] Prag *et al.*, *op. cit.* (*supra*, n. 49).

[88] These factors were republished by D. Frankel, R. Hedges and H. Hatcher, *RDAC* (1976) 35-42.

[89] eg. Mg 3-4%, Ca 10-15% and Fe 7-9%.

relates to the last point, the working criteria and *desiderata* of the archaeologist and scientist in this field have altered greatly. All aspects of the planning of a composition and provenance study have been refined; stricter control over the choice of material, and the need for a larger number of control samples to be analysed are but two aspects which may be highlighted. The FL retains copies of all the control data obtained for the Aegean sites by the OL, only half of which has been published.[90] The FL's policy towards the OL's pre 1970 data, which it has not had the opportunity to state publicly until now, is:

1. To treat the data in the first instance as a primary data set. Its principal value rests in the comprehensiveness of its coverage of the Late Bronze Age Aegean; besides the sites listed by C and M,[91] several additional sites in Boeotia and Crete have been covered.

2. To use the data indirectly in current work. The statistical analysis of old composition data is treated separately and independently to that of currently derived data. There is, however, a sufficient measure of agreement between the two sets of data, the former after the application of the conversion factors, for the FL to use individual and group compositions for reliable *background* information. A good example of this has been given above in connection with the Cretan compositions; the data for Zakro, Piskokephalo, Gournia, Pseira, Myrtos, Ayia Triadha, Phaistos, Tylissos, Perama and Nochia were all obtained at the OL before 1971.

We hope that the results presented here will at least partially satisfy the main critics of the earlier analytical work. It is in the area of data interpretation, particularly, that there has been necessary and drastic improvement. The process of setting up a data bank involving the computerising of all the accumulated data from the two labs[92] should stimulate the use of multivariate analysis of data as a matter of routine. An additional benefit that may accrue from this operation will be an easing of the problems of long term reproducibility, problems which have been faced but must be fully resolved. On the other hand, a corresponding improvement in the choice of elements to be determined may appear to be lacking. This choice is under review, but all attempts to identify additional or alternative elements to the nine already measured have so far proved unsuccessful except in a few limited cases. The evidence would in any case have to be very convincing for a decision to be taken either to drop one of the traditional elements or to adopt a new one, simply because of the implications this would entail. In using OES, the OL and FL have deliberately sought to maintain a reasonable balance between, on the one hand, relatively rapid and efficient output of analytical data and, on the other, the need for the data to be as informative for provenance purposes as possible.

The Linear B Inscriptions

I discuss here the relationship of the results of the clay analysis of the ISJs to the painted Linear B inscriptions which many of the vessels carry. I begin by listing the material tested, site by site, in the groups produced by the 'visual' classification described on p. 63 of the paper. I then comment on:

I. The extent to which the groupings produced by the visual classification are matched by groupings in the inscriptions;

II. the differences, at mainland sites, between the inscriptions on locally produced vessels and those on imported jars; and

III. the implications of the results for Cretan geography.

[90] This regrettable fact will be rectified in a forthcoming publication by REJ (*supra*, n. 40).

[91] A. Millett and H. W. Catling, *Archaeometry* x (1967) 70-77.

[92] This is currently taking place at Oxford with the cooperation of the University's computing centre and through the use of its ICL 2980 computer. The scheme was initiated by R. Hedges and Professor J. Boardman.

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A The Material

Note: The numbers shown in the first two columns in the tables beneath are (a) the reference used in the present paper and (b) either the (Z) reference number in *CIV* or in *VIP*, or in the absence of a Raison number, the museum inventory number. The text of the inscription is noted in column 3: except where indicated otherwise, the text quoted is that in Sacconi.

In all cases, the grouping shown is that produced by the visual classification. In a few cases, jars which have been assigned to W Cretan β on visual classification have been assigned to W. Cretan Group α by the discriminant analyses (see p. 78), and where this has happened the relevant entry is shown in the tables surrounded by dotted lines.

Thebes

No.	Z No.	Inscription

"Thebes-Knossos"

11	859	**	(⊖)
12	860	**	(⊕)
13	861	**	(⊖)
14	862	**	(⦶)
18	866	ị-ṛụ	
19	867	ị-ṛụ	
20	868	ṛụ-ị	
41	967	** ? (i)	
42	973	** ? (ii)	

** = Potter's mark

W. Cretan α

1	840	ku-ru-zo
2	841	ku-ru-zo
3	842	a-do-we
4	844	ḳụ-jạ-ni
15	863	a-nu-to
16	864	a-nu-to
17	865	a-nu-to
21	869	ta-de-so
22	870	]de-so
23	871	ta-*22-de-so
26	876	ta-*22-de-so
29	879	ku-]ru-zo
31	881	]ni (iii)
38	961	a-]nu-to

W Cretan β

5	849	a-re-zo-me-ne wa-to, re-u-ko-jo
6	850	e-wa-ko[-ro], ka-ma-ti-jo-jo
7	851	a-ṛẹ-zọ-me-ne wa-to, re-u-ko-jo
8	852	a-re-me-ne wa-to, re-u-ko-jo
9	854	]pi-pi, wa-to, su-ru-no
10	855	wo-[.]-da
24	872	ta-]*22-de-so
25	873	**
27	877	ti-tu[
28	878	wa-]to, su[-ro-]no[
30	880	]ni-jo-jo[
32	882	]-ne[wa-]to[ ]re-u-ko-jo
33	883	e-wa-ko-[ro
34	884a	e-wa]-ko-ro
36	958	]e[
37	960	ku-]ṛụ-zo
39	962	]jo
40	966	]wạ-wọ[(iv)

Notes: (i) Sacconi takes the sign here as a potter's mark. Raison is uncertain whether it is a potter's mark or a syllabic sign (*a* or *wa* ??). (ii) Sign (circular) again taken as a potter's mark by Sacconi. Raison hesitates between a potter's mark and a sign (*ka*) in a vocabulary word. (iii) As Raison points out (p 117), the *ni* here resembles that on 4 = Z 844 (*ku-ja-ni*), in that it is painted on its side and not upright, and it is quite possible therefore that both vessels carried the same inscription. (iv) Reading very uncertain; perhaps not a genuine inscription at all.

Orchomenos

W Cretan β

43	1	ti-sa-ri-[.]

Eleusis

W Cretan β; perhaps between Chania & Knossos

44	1	.1 da-*22-to .2 da-pu_2-ra-zo, wa,

Mycenae

(Probably locally produced)

46	712	pi-ra-ki
47	713	.a]ṃạ-pu[.b] ka [
48	714	]pi-ka [
49	715	]ra-u-ko
50	717	ka-ra-ụ-ko (i)
51	50-580	?

W Cretan β

45	202	]e-ra, ka-ta-ro

Note: (i) 1975 Excavations: see J.L.Melena, *Minos* 16 (1977) 17f.

Tiryns

(Probably locally produced)

60	—	?

W Cretan α

54	19	]no[
55	24	a-ḍọ-wẹ[
57	36	]u
58	39	]ru[
59	37	]no[
62	18	]no[
63	17	]no[
65	15	no-di[-zo
66	19	]ja-ti[
70	—	? (i)
71	30 + fr	]du-ne-u

Note: (i) 1978 excavations.

W Cretan β

52	1	u-pa-ta-ro
53	11	]no-di-zo[
56	34	]u-ṇọ
61	4	]u-pa-ta[-ro
64	31*	illegible
67	6	a_3-ṭạ-[
68	21	]no[
69	—	?

Knossos

(Probably locally produced)

72	1715	[.]-*89-a
73	1716	wi-na-jo

Chania

W Cretan α

76	3	]ma-di-jo[
78	5	]de-ṣọ[
79	6	]ka[
81	8	]-pạ[
82	9	]u-[
85	12	]ṭạ

W Cretan β

77	4	]pu-ti[
80	7	]to
83	10	]pu-ti[
84	11	ẹ[
87	14	]ḳạ[
88	15	]*56[
89	16	wa [incised] (i)

Note: (i) 1976 excavations: See E Hallager, B Vlasakis, *AAA* 9 (1976) 213ff.

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(Uncertain: Knossian??)

74	1	ka-ṛụ-ḳạ[
75	2	]ṃạ-i-jo

(Uncertain)

86	13	]pạ[

B Comment

I. The groupings produced by the visual analysis and groupings in the inscriptions

As can be seen at once, the evidence of the inscriptions provides strong general support for the validity of the visual classification. In a number of cases among the vessels tested, two or more jars carry the same (or a virtually identical) inscription; and in all such cases the vessels in question fall into the same grouping suggested by the visual classification (local, W. Cretan α, W. Cretan β), or at least cannot be shown to belong certainly to a different grouping.[93] This applies both to two or more vessels at the same site showing the same inscription, and to two or more vessels at different sites showing the same inscription. In all these cases, the inscriptions in common between the vessels not only have the same (or a closely similar) wording (and a similar position on the jar), but are also in very similar script: very likely indeed, because the same scribe has written them—though we cannot perhaps finally exclude an alternative possibility, that they have been written by two or more different scribes who have copied from the same standard pattern.[94] The full details are as follows:

(a) The same inscription at the same site

Thebes

(i) **18** = Z 866 (*ị-ṛụ*), **19** = Z 867 (*ị-ṛụ*), **20** = Z 868 (*ṛụ-ị*), (i.e. *ị-ṛụ* reversed). All local; no other example of inscription known.

(ii) **15** = Z 863 (*a-nu-to*), **16** = Z 864 (*a-nu-to*), **17** = Z 865 (*a-nu-to*), **38** = Z 961 (*a-*]*ṇụ-to*). All W. Cretan α; no other example of inscription known at Thebes. TI Z [8 + 26] (*a-nu*[*-to?*) not analysed: see further below.

(iii) **1** = Z 840 (*ku-ru-zo*), **2** = Z 841 (*ku-ru-zo*), **29** = Z 879 (*ku-*]*ru-zo*). All W. Cretan α. **37** = Z 960 (*ku-*]*ṛụ-zo*) (W. Cretan β) on visual classification; but according to discriminant analyses "falls into the 'uncertain' zone between the two groups, and is in fact more like a member of the α group than most of the other β members" (J. Cherry).

(iv) **21** = Z 869 (*ta-de-so*), **22** = Z 870 (*?ta-*]*de-so*), **23** = Z 871 (*ta-**22*-de-so*), **26** = Z 876 (*ta-**22*-de-so*). All W. Cretan α. **24** = Z 872 (*ta-**22*-de-so*) W. Cretan β on visual classifi-

[93] As will be noted in more detail below, in a few cases jars which carry the same inscriptions fall into different sub-groupings (α, β) within the W. Cretan material. In all these cases, however, the aberrant vessel proves on investigation to fall into an uncertain 'middle zone' between the two groupings.

[94] We can surely exclude a third possibility, suggested by E. Hallager in his discussion of the resemblances between **78** = KH Z 5 (]*de-ṣọ*[) and the Thebes jars carrying the name *ta-de-so*, *ta-**22*-de-so*, that the similarities are due to a scribal tradition (OpAth 11 (1975) 67 f). Given the wide variety of the signs found on jars, it is difficult to believe that there can have been a strong tradition as to how any of them should be written; and the chances of the similarity between the *de*'s on the Chania and Thebes vessels in question being due to scribal tradition have been reduced by the discovery (since Hallager wrote) of a *de* on a Mycenae pottery fragment (Z 716) which is of a quite different pattern (and much more like the *de*'s found on the tablets).

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cation, but discriminant analyses suggest re-classification as W. Cretan α (see p. 78), or at least as 'uncertain'. No other example of inscription known at Thebes; on **78** = KH Z 5 *]de-so[* see further below.

(v) **9** = Z 854 (*]pi-pi, wa-to, su-ro-no*), **28** = Z 878 (*wa-]to su[-ro-]no*). Both W. Cretan β. Z 846 (*pi-pi, wa-to, su-ro-no*) not analysed.

(vi) **6** = Z 850 (*e-wa-ko[-ro], ka-ma-ti-jo-jo*), **33** = Z 883 (*e-wa-ko[-ro*), **34** = Z 884α (*e-wa]- ko-ro*). All W Cretan β. No other example of inscription known.

(vii) **7** = Z 851 (*a-re-zo-me-ne wa-to re-u-ko-jo*), **8** = Z 852 (*a-re-me-ne, wa-to, re-u-ko-jo*). Both W Cretan β. Z 849 (*a-re-zo-me-ne wa-to, re-u-ko-jo*) not analysed. **32** = Z 882 (*]ne[wa-]to[ ]re-u-ko-jo[*) W Cretan β on visual classification, but discriminant analyses suggest reclassification as W Cretan α or, perhaps safer, as uncertain.[95]

Note also:

(i) **4** = Z 844 (*ku-ja-ni*), **31** = Z 881 (*]ni*). Both W. Cretan α. The *ni*'s in both inscriptions are closely similar (both are on their sides, rather than upright), and it is tempting to restore **31** as *ku-ja-]ni*.[96]

(ii) All the vessels in the test sample which show a potter's mark of the circular variety (⊕, ⦶ or ⊖) are Theban-Knossian. Indeed, all the potter's marks on these vessels may be of the circular type. A possible exception is on **25** = Z 873; but it is not certain whether the sign in this instance is a potter's mark (as Sacconi suggests) or a syllabic sign (*a* or *wa*).[97]

(iii) All the jars which bear the place name *wa-to* are W Cretan β: see further below.

MYCENAE

(i) **44** = Z 715 (*? ka-]ra-u-ko*), **50** = Z 717 (*ka-ra-u-ko*). Both locally made; no other example of inscription known.

TIRYNS

(i) **52** = Z 1 (*u-pa-ta-ro*), **61** = Z 4 (*]u-pa-ta-ro[*). Both W. Cretan β.

(ii) **65** = Z 15 W. Cretan α; **53** = Z 11 W. Cretan β on visual classification, but discriminant analyses suggest reclassification as W. Cretan α (see p. 78).

(b) The same inscription at different sites.

THEBES, TIRYNS

Thebes:— **3** = Z 842 (*a-do-we*); Tiryns:— **55** = Z 24 (*a-do-we[*). Both W. Cretan α. TI Z 25 (*]a-do-we[*) not tested.

THEBES, CHANIA

Thebes:— **21** = Z 869 (*ta-de-so*), **22** = Z 870 (*]de-so*), **23** = Z 871 (*ta-*22-de-so*), **26** = Z 876 (*ta-*22-de-so*); Chania:— **78** = Z 5 (*]de-so[*). All W. Cretan α. **24** = Z 872 (*ta-]*22-de-so*) W. Cretan β on visual classification, but discriminant analyses suggest reclassification as α or, at least, as uncertain; see above.

As has already been noted in the main body of the paper, the suggestion that **78** = KH Z 5 is in the same scribal hand as the Thebes vases with *ta-de-so, ta-*22-de-so* has previously been

[95] J. Cherry, *per litteras*. [96] See *VIP* 117. [97] See *VIP* 102, n. 78.

made by a number of scholars (including the present writer),[98] on the grounds particularly of the idiosyncratic forms of the *de*'s in all cases (which are quite unlike any of the forms of *de*'s found on tablets). If the suggestion were confirmed, it would obviously have important consequences for the dating of the stirrup jars; clearly, for instance, it would no longer be possible to believe that the Theban ISJs were some 75-100 years earlier than the Chania fragment.[99] However, while the epigraphic evidence and the findings of the clay analysis are both clearly consistent with the hypothesis, it would probably be unwise to rule out entirely the alternative possibility (mentioned earlier), that these are inscriptions written by two or more different scribes who are copying from the same standard pattern.

No analysis has been carried out on TI Z [8 + 26] (*a-nu-to*); it would be interesting to discover if this had the same composition as 15, 16, 17 and 18, all of which show the same term. Similarly, it would be interesting to discover if TH Z 857, 858 (*di-no-zo*) had the same composition as TI Z 11 (= **53**), 12, 13, 14, 15 (= **65**), 16 and 23. All of the latter show, or may show, the word *no-di-zo*, and there are good reasons for believing that *di-no-zo* is a miswriting of *no-di-zo*.[100]

A final point of interest to arise under this heading is that all the jars at Thebes which contain inscriptions of the pattern personal name, place-name, personal name (NPN) fall into W. Cretan β, and that the same is true of **45** = MY Z 202, which may have an inscription of the same pattern (]*e-ra, ka-ta-ro*: see further below). As has long since been observed, the second personal names (in the genitive) in these formulae are strongly reminiscent of the additional "collector's" or "owner's" names (also often in the genitive) which appear on a number of the sheep records in the D series in the Linear B tablets from Knossos;[101] and it is clearly tempting to wonder whether the clustering of names of this type on jars in W. Cretan β may not reflect a division between "collector" and "non-collector" similar to that found on the Knossos tablets, where not only do "collectors" or "owners" have separate flocks and workshops, but where the produce of these flocks and workshops (and the flocks themselves) are recorded on separate totalling tablets.[102] Does the appearance of these additional names only on vases in W. Cretan β reflect the fact that they refer to "owners" *vel sim.* who had separate pottery workshops; and does the regular appearance of the name *wa-to* on these vessels mean that there was a marked tendency for "owner" workshops to be located at *wa-to* or at least to be concerned with oil which had been produced at *wa-to*?[103] It is no objection to this suggestion that W. Cretan β, both at Thebes and (particularly) elsewhere, also includes vases whose inscriptions are of a different type: these could be the products of "non-owner" workshops which happened to use the same sources for their clay as the "owner" or "collector" establishments.

II Differences between locally produced and imported jars in terms of their inscriptions

Now that the clay analysis enables us to distinguish between locally produced and imported vessels at the mainland sites, it is of interest to see whether there are differences between the

[98] Hallager, *loc cit* (n. 3 above); J. Raison, *Nestor* (1 November 1975) 1016; L. Godart, *PdP* 31 (fasc 166) (1976) 121; J.T. Killen, *Mycenaean Geography* (ed. J. Bintliff) (1977) 46. For further discussion, see S. Hiller, *Kadmos* 15 (1976) 112.

[99] Cf. Hallager, *op. cit.* 74.

[100] See Raison, *op. cit.* 80.

[101] G.R. Hart, *Mnemosyne* 18 (1965) 19.

[102] In the Dn flock totalling records separate figures are provided for "collector" and "non-collector" animals (see J.P. Olivier, *SMEA* 2 (1967) 71-93); Lc (1) 535 is likely to be the totalling record for the "collector' workgroups in the Lc (1) CLOTH series (see Olivier, *op. cit.* 91); and a similar distinction between "collector" and "non-collector" may be made in totalling records for the Ld (1) series (see J. T. Killen, *Colloquium Mycenaeum* (Actes du sixième colloque international sur les textes mycéniens et égéens tenu à Chaumont sur Neuchâtel du 7 août au 13 septembre 1975) (1979) 155.

[103] For further discussion on whether the place-names on jars indicate where the vessels themselves were made or where there contents were produced, see Section III below.

two classes in terms of their inscriptions. In fact, relatively few clear patterns emerge. The sharpest differences between the two classes are at Thebes, where all the vessels which lack inscriptions, and all but one of these which carry only potters' marks, prove to be of probable local manufacture. In addition, the potters' marks on the locally produced vessels may all be of the circular type (⊕, ⦶ or ⊖) (though a doubt remains over **25** = Z 873: see earlier); whereas the only potter's mark on an imported vessel among the test sample is of a different pattern (it resembles an inverted *wa*). Moreover, the three actual inscriptions on the locally produced vessels (**18**, *i̥-ru̥*; **19** *i̥-ru̥*; and **20** *ru̥-i̥*) differ from those on the imported jars in that they are incorporated into the decoration on the belly or shoulder of the vase, and are not shown on an otherwise clear panel or band. What is more, none of these three inscriptions is written in a manner which suggests that their painter was closely familiar with Linear B, at least in the form in which it appears on tablets. The *i*'s on **18** and **19** have an odd additional element to the right which is not found on *i*'s on the tablets; and three *ru*'s have a most idiosyncratic form, for which there is again no parallel in the tablets (though a partial parallel would be provided by the second sign on KH Z 1 (= **74**) if this really is *ru* and not *sa*). In fact, given these oddities (and the inversion of *i̥-ru̥* as *ru̥-i̥* on **20**), one is half inclined to wonder whether these are genuine inscriptions at all, rather than decorative motifs, like the nonsense writing in alphabetic script which is used as decoration on vases of a much later period. (It is worth noting in this connection how the curves of the *ru*'s in all three cases are matched by the curves of the surrounding decoration, and it would be interesting to know which of the two came first.) In contrast to these rather unconvincing local inscriptions, many of those on the imported vessels are quite elegantly written.

At other sites, however, the distinction between local and imported is a good deal less sharp. Not only are some of the imported vessels at other sites uninscribed (of Mycenae, in particular, only one of the imported vessels in the test sample carries an inscription, while most of the local material does have a legend of some kind): there is also no repetition elsewhere of the Theban pattern of local vessels carrying poorly written or unconvincing inscriptions and the imported material showing legends of a much higher quality. It would be misleading to describe **43** = OR Z 1, for instance, as a particularly impressive example of Linear B: whereas the inscriptions on **49**, **50** = MY Z 715, 717, are perfectly respectably written, using more or less the canonical forms of the signs known from the tablets.

III The implications of the results of the analysis for Cretan geography

The most clear-cut result of the analysis as far as Cretan geography is concerned is that mentioned in the main body of the paper, ie the confirmation that the Theban jars which show the place-name *wa-to* come from the west of Crete, and not the far east. On the Linear B tablets from Knossos, *wa-to* is particularly associated with a group of six toponyms, two of which, *ku-do-ni-ja* and *a-pa-ta-wa*, are clearly Kydonia and Aptera in the far west of the island; and when it was believed, as the result of C and M's earlier analyses, that the ISJ's which referred to *wa-to* and *o-du-ru-we* came from the far east of Crete, it was necessary, in order to reconcile this finding with the tablet data, to suppose the existence of an 'outer' administrative area of the island, including places in both the far east and the far west of the island. With the new result, however, all is very much simpler: all these places (as L.R. Palmer and L. Godart had previously maintained on the basis of the tablet evidence) are in the far west.

A further question at once arises, however. When we find the name *wa-to*, for instance, on a jar, does it mean that this was the place where the *vessel* was produced, or the place where its *contents* (most likely oil) were produced? It has been noted earlier that some support for the view that the place-names indicate the place where the jar itself was produced seems to be provided by the analyses of 44 = EL Z 1, which shows the place-name *da-*22-to*. From its associations on the Knossos tablets, we can conclude that this was a place in the central zone of the island, not in the far west, though there is much to suggest that its particular associations are with the western sector of the central region;[104] and it is encouraging for the belief that 44 was actually produced at *da-*22-to* that its clay composition appears to mark a mid-point between that of the Chania vessels and that of the two Knossos jars in the test sample.

Before we regard this question as finally settled, however, it would be desirable to have some further confirmation of the 44 result; and an obvious next step would be to test the clay of TI Z 27, which carries the place-name **56-ko-we*. It is clear from the Knossos Linear B data that **56-ko-we* and *da-*22-to* were places in close proximity to one another;[105] and the discovery that TI Z 27 had a similar clay composition to 44 would obviously lend considerable strength to belief that the latter was actually produced at *da-*22-to*.

Another question on which it would seem premature to reach any firm conclusions at present is whether the jars which show W. Cretan place-names like *wa-to* come from Chania or its immediate vicinity: which, if 44 comes from *da-*22-to*, would clearly suggest that these were places in the immediate neighbourhood of Chania. The case for believing that they do come from the neighbourhood of Chania is obviously strong: there are sources for clay similar to theirs in the immediate vicinity of the modern town (see p. 81 above); and the Chania ISJs include vessels of a similar composition. But we still know too little about the clay of other areas of W. Crete to be able to rule out the possibility of an alternative provenance.

This same uncertainty prevents us from drawing any firm conclusions at present from the evidence of 45 = MY Z 202. This reads]*e-ra, ka-ta-ro*; and while *e-ra* is not certainly complete, it is tempting to suppose that this is part of an NPN formula of the *a-re-zo-me-ne wa-to re-u-ko-jo* type, and to take the term as the place-name *e-ra* attested on the Knossos Linear B tablets.[106] (Though *ka-ta-ro* is not certainly a personal name, there is no reason why it should not be.) The clay analysis of the jar, moreover, confirms that it is of Cretan origin. What is of interest, however, if the jar really does refer to *e-ra*, is that its clay is of the W. Cretan α variety, ie. is similar to that of a number of the Chania ISJs; for it is clear from the Knossos tablets that *e-ra* is in the central part of the island and not the far west (though it may have associations with *da-*22-to*, and hence perhaps with the westerly half of the central region).[107] Is this, then, evidence which runs counter to that of 44, and which suggests that jars were not always made in the areas whose name they carry; or does the fabric of 45 = MY Z 202 only resemble that of the Chania vessels because there were a number of alternative sources for this variety of clay either in or towards the west of the island? Only further investigation will allow us to provide an answer.

Archaeological Comment

The results of the Theban investigation described by C and J in *Archaeometry* 19 foreshadowed those described here, emphasizing very strongly the importance of the role of Chania as the Late Minoan period drew to its close—certainly its role as a centre of literate bureaucracy. 83% (64 out of 77) of the "true" ISJs studied in the sampling programme have been attributed to Chania. Thirteen of these jars were found at Chania itself, but many others were found far afield, at Mycenae, at Tiryns, at Orchomenos, and above all, at Thebes. The

104 In the Dn SHEEP totalling records (see Dn 1093), it is associated with **56-ko-we*, and this in turn has associations with *ku-do-ni-ja* (see eg G 820) and with other places known to be in or towards the west.

105 See the previous note.

106 For further discussion of this question, see L.R. Palmer, *Colloquium Mycenaeum* (1979) (see n. 10 above) 48.

107 For possible evidence for links between *e-ra* and *da-*22-to*, see Palmer, *loc cit* 44 ff.

jar from Eleusis, of somewhat divergent composition, may have come from a site between Chania and Knossos. Five more jars (**36**, **69**, **74** and **86**)—6.5% of the total—have compositions of uncertain origin. Four more ISJs—**18**, **19** and **20**, found at Thebes, and **73**, found at Knossos—belong to the composition type common both to Knossos (and, for that matter, to a not inconsiderable area of central Crete), and to Thebes, Unfortunately, therefore, of those jars it can only be said that any one of them could come from either central Crete (including Knossos) or from Thebes. It is very striking that five out of the six Mycenae ISJs that were sampled should have proved to be locally made. This is in marked contrast with the results from Tiryns, only a few kilometres away, where, of twenty ISJs sampled, 18 have been attributed to Chania, while the origin of one remains uncertain and the last, **60**, was locally made. It is possible that **60** was made in the same place as the five locally made Mycenae ISJs.

Had we analysed a larger number of ISJs, we believe the overall result would probably have been substantially representative of the whole corpus. In particular, several of Raison's "Groups' have been well covered (especially the "Group of Thebes 853", the "Group of Thebes 858" and the "Group of Tiryns 11"). Our results harmonise satisfactorily with his, which were based on combinations of typological and epigraphic similarities. The only disagreement occurs over the Theban **42**, whose analysis attributes it to a "local" origin (ie Thebes/Central Crete). Raison includes it in his "Group of Thebes 853", much the largest of his groups, accounting for more than thirty of the Theban total. We sampled fifteen of these, fourteen of which have compositions of Chaniot type. The discordant **42** is a small fragment, only preserving part of a single syllabic sign. **42**, in fact, was dropped by Sacconi from the ISJ corpus on the ground that the sign is part of a pot-mark and not a true inscription. Be that as it may, we consider our results suggest that **42** should be detached from the "Group of Thebes 853". In all probability, the analysed members of his groups would take with them the unanalysed jars in the same groups. Were that the case, up to 34 more ISJs could immediately be attributed to Chania. We hope shortly to put this hypothesis to the test in the supplementary programme to which reference has already been made.

It seems clear that the dominant role in organising the movement of the commodity (ies) for which this type of container was required, and in submitting it to the organisational procedure that culminate in the issue of inscribed jars, was played by West Crete—which, in all likelihood, must mean Chania. The significance of this result in terms of Linear B studies has been explained by Dr Killen. It remains to examine the more strictly archaeological consequences of our investigation.

The Date of the ISJs

When C and M published their results in 1965 they stressed the significance of the *date* of the ISJs—"It is almost as important to know the date when the Theban jars were made as to find out where they were made". Now we believe we have the correct answer to the second part, it is to realise that the first part is really of *equal* importance. Ironically, it seems to be more difficult to argue convincingly for the date of the ISJs than for their origin. A word is needed to explain why the date of the ISJs is important. Firstly, it has become very much more important than it was before the attribution of a majority of the jars to western Crete. When it was still just possible to believe that all the jars were made where they were found, interesting though the date(s) of manufacture may have been, these dates did not carry implications for the interpretation of highly controversial aspects of Minoan-Mycenaean history. The discoveries made at Chania since 1962 by Y. Tzedakis, J. Papapostolou and others leave no doubt at all that Chania was an administrative centre of major importance during the Late Minoan period. The discovery in 1973 of a small archive of Linear A tablets and inscribed roundels in a LM I context[108] immediately placed Chania in the first rank of Minoan centres in the period before the LM IB destructions. That fact alone is of great historic importance and interest. The discovery from 1962 onwards of fragments of ISJs with Linear B inscriptions suggested that here at last was a Cretan site that broke the Linear B monopoly of Knossos. We say " suggested", for there was no immediate proof that these were fragments of ISJs that had been *made* at Chania. For the time, at least, they could as well have been imports to Chania as locally produced. Now we propose the majority was locally made; that means the existence at Chania of bureaucratic skills and the administrative structure for which such skills were exercised not only at the date when Linear A had been the medium of expression, (very interesting, but uncontroversial) but at the date(s) when Linear B had replaced the earlier script. No archive of Linear B tablets has yet been found in the Chania excavations, but one does not require unusual prophetic gifts to predict that sooner or later such an archive must be forthcoming.

This brings us straight back to the 20-year old controversy over the date of the Knossos Linear B archive with which this paper began. The existence of a second administrative centre in Crete in the years of Mycenaean domination makes a great difference to our concept of the manner in which the island functioned in the last centuries of the Bronze Age. This much is true wherever we date the Knossos tablets, wherever we date the Chaniot ISJs. But the value of the information increases enormously if we can place the activity of the Chania administration *closely* in relation to Knossos, *closely* in relation to the activities of the administrative centres of the Mainland. Were Knossos and Chania functioning simultaneously as such centres? Were their activities contemporary with those of the Mainland bureaucracies? If we continue to accept the early 14th century BC date for the Knossos archive are we committed to the assumption that there was a single administrative centre in the early 14th century—Knossos—and that its role was inherited by Chania for the 13th century BC? Do we think, on the other hand, that a 13th century date for bureaucratic activity at Chania has anything to tell us about the probable date of the Knossos archive? Are the several strands of evidence linking Knossian bureaucracy with Chania and *its* bureaucracy, Chania with bureaucratic centres on the Greek Mainland and, by implication, from them back again to Knossos, now so inextricably interlocked that a firm chronological decision for anyone of them has inescapable conclusions for the remainder?

A definite commitment to any particular views will almost certainly fail to earn universal assent. The implications of reviewing this evidence are potentially of gravity for certain cherished beliefs; it is important to set them out for there seems an opportunity to detach much of the Knossos dispute from the immensely complicated intricacies that have resulted from the attempts over the years to reconstruct the stratigraphy of the site in terms of the knowledge available in the 1960's and 1970's from observations made by those working in the half-light of the dawn of Minoan archaeology.

So let us consider first the chronology of the ISJs, and in particular those we have reason to believe were produced in Chania. Immeasurably the most important group is that found by Keramopoulos in the so-called Kadmeion at Thebes. They are important because there are so many of them; they are important because they were evidently all found together; they are also important because so many of them are substantially complete. On the face of it, a date for the context of so large a group of material ought not to be difficult to establish. But, as everyone

[108] Papapostolou in *AAA* 8 (1975) 42-45; Papapostolou, Godart and Olivier, *Grammiki A sto Minoiko Archeio tôn Chaniôn* (Rome, 1976). Note also, Papapostolou's publication of the sealing from the same find, *Ta Sphragismata tôn Chaniôn* (Athens 1977).

who tackles problems of Theban chronology ends by ruefully admitting, the evidence is less than secure, despite some very confident assertions to the contrary. The extreme range of possibilities extends from *c* 1400 BC (a position adopted very positively by A. Furumark) to a date well within the 13th century BC (of which probably Raison has been the most thoughtful protagonist). Middling suggestions have been made by G. Symeonoglou in the light of his own excavation in Thebes, recently published in detail in *Kadmeia* 1; he would put the ISJ deposit in the Kadmeion early in LH IIIA2—say, in the second quarter of the 14th century BC. This is a difficult problem, possibly aggravated by the assurance with which Keramopoulos and, after him, Furumark and Ålin argued for a date close to 1400 BC for the contents. Furumark, it must not be forgotten, spelled out his views quite unequivocally, "The great amount of pottery found in the burnt layer (fragments of *c* 250 vases, nearly all plain), apparently in unused condition and manufactured within the palace, must all be contemporary with the final destruction. The same must be true of the big false-necked jars (type 164). At later unpublished excavations over 100 more of these have been found, all of the same type, also other pottery exactly corresponding to that found in the burnt layer."[109] Later, Furumark was to say, "I have examined the unpublished finds in the Museum of Thebes: all those belonging to the actual floor deposit are of Mycenaean III A1 date."[110]

Dating and the architecture of Thebes

It is not possible to express any view on the date of the Kadmeion deposit without taking note of the controversy over the number of successive Mycenaean palaces in Thebes, and their supposed dates of destruction. Equally, however, this is not the place for a complete review of the evidence and arguments. In brief, it has long been known that the Mycenaean buildings, fragments of which have been revealed from time to time in rescue excavations in Thebes, are on two different alignments. The contents of rooms, etc, found in both cases have frequently been of such value and importance as to suggest to their discoverers a palatial identity for their find places. In one particular instance, at the Oedipus Street site, excavated, studied and published by G. Symeonoglou,[111] a later building complex was found over an earlier building complex, their orientations different, each corresponding to one of the previously recognised palatial alignments (the earlier Oedipus Street building on the same alignment as the Kadmeion = the Early Palace, the later Oedipus Street building in the same alignment as other "palatial" fragments = the New Palace). It has been supposed (though without any close consensus) that the Early Palace (including Keramopoulos' Kadmeion and its ISJ and SJ store) was destroyed during LH IIIA, while the New Palace, including those buildings in which Linear B tablets have been found, was destroyed during LH IIIB. If this scheme is correct in essentials, then the context of the Theban ISJs is to be dated somewhere in LH IIIA.

The most recent summary of the position has been given by Hope-Simpson and Dickinson.[112] Th. Spyropoulos[113] has reviewed the problem thoroughly, arguing for the existence of a single palace, not two, maintaining in fact that the Mycenaean palace proper has not yet been found, and may perhaps lie under the modern square. Reviews of *Kadmeia* 1 have also focused attention on the "Two-Palace Problem", though their reactions have not led their authors to as radical a solution as Spyropoulos'. A. M. Snodgrass, for instance,[114] is sympathetic to Symeonoglou's general thesis, though he sees no need for the destruction to be as *early* in LH

[109] *CMP* 52.

[110] *Op Arch* VI (1950) 264, n 4.

[111] *Kadmeia* 1.

[112] *GAC* 244-245. Th. Spyropoulos (with J. Chadwick) *The Thebes Tablets II: Minos* Supplement 4 (Salamanca 1975).

[113] See also Spyropoulos in *AAA* 4 (1971) 32 ff.

[114] *Gnomon* 47 (1975) 313-316.

IIIA2 as Symeonoglou suggests. J. B. Rutter[115] sharply calls into question an early date in LH IIIA2 for the earlier destruction, though he implicitly accepts the existence of two palaces. Rutter does not consider that Symeonoglou has made a case for the construction of a New Palace before the end of LH IIIA2. Raison[116] is a strong supporter of the single palace argument, with which he has been in favour for some time.[117]

One or two arguments may be brought forward to support the single palace theory (which does not necessarily commit one to any single chronological position, it should be noted). Firstly (this point has certainly already been made by Raison and Spyropoulos, but it requires the strongest emphasis) life would be a great deal simpler if it was conceded that a difference in alignment did not automatically exclude contemporaneity, and similarly, buildings can be similarly aligned without necessarily being contemporary. In some cases the contrary arguments put forward in the case of Thebes strain credulity; buildings on the same alignment and therefore supposed to be contemporary with each other and part of the same architectural complex are nearly 200 m apart.[118] (This is the distance by which Keramopoulos' Kadmeion is separated from Symeonoglou's Oedipus Street site). This would mean that the palace layout at Thebes had been at least twice the greatest dimensions of the Palace at Pylos, that it was substantially larger than the Palaces of Phaistos and Mallia, very much larger than Zakro and a trifle larger than the Knossos Palace. While this is conceivable, it is unlikely.

It is surely more likely to lead to an accurate understanding of the nature and functioning of the Mycenaean settlement at Thebes if, for the time being, at least, less effort goes into the attempt at relating disjointed parts of the site to one another on the basis of a supposed chronological relationship between similarly aligned building lines, no matter where they are.

A useful substitute for this activity would be the study and publication of the material from those sites that go to make up the jigsaw puzzle that have not yet made their full contribution to our understanding. Symeonoglou,[119] Spyropoulos[120] and A. Demakopoulou-Papantoniou[121] have already shown us what must be done. That mere alignment as an argument for contemporaneity or otherwise can be a ludicrous method of working is very well illustrated by the recent experience of M. R. Popham and L. H. Sackett at Knossos in the Unexplored Mansion.[122] This building, as is now familiar, had probably first been constructed in LM I—was used and destroyed violently in LM II, after which its northern half was dug out and reoccupied, while its southern half was left a ruin. In the northern, LM III half, a complete ISJ was found. That find no more dates the contents of the southern half of the building (all LM II) to LM III, than the LM II groups in the southern half of the building make the ISJ of LM II date. Yet the "alignment" is one and the same, for the building is one and the same, but that does not prevent the fact that its two halves have quite different histories. Nor is it on the same alignment as the Little Palace, next door, any more than the Little Palace is on the same alignment as the Palace itself. With due respect to those Theban scholars who have involved us in the game of alignments, the sooner it is forgotten, the better.

A second misconception has been allowed to colour interpretation of the Theban remains. In brief, that is that every building in Thebes that comes to light containing important, valuable or interesting material remains has to be part of the Palace. If these arguments were extended to Mycenae, then most of the houses outside the Citadel would qualify for palatial

115 *AJA* 78 (1974) 88-89.

116 *RA* 1977, 79-86, esp 83ff.

117 *VIP*.

118 As Snodgrass has already pointed out, *Gnomon* 47, 313.

119 *Kadmeia* I.

120 *Thebes Tablets* II.

121 *AAA* 7 (1974) 162-173.

122 *AR* 1972-73, 50ff.

status. It is, surely, not the *contents* of a building that is the prime evidence for its identity, but its architecture. Use of the word "palace" is sometimes self-defeating; it has certainly been unhelpful in Thebes so far as the building remains already uncovered are concerned. Some of the misplaced enthusiasm for the "alignment game", already mentioned, stems from the premature use of the word "palace" for these remains. (Saying this does not mean there *is* no palace at Thebes; fairly obviously, there must be, but the very fragmentary architectural remains we know could only be identified as a palace by the assumption (which is, indeed, made by some scholars) that the Thebes palace is not of mainland, but of Cretan type. Even if the latter view were correct, the evidence for it is not yet available).

A misconception of a different kind seems to be inherent in Symeonoglou's arguments for dating Keramopoulos' building, the Kadmeion. Having argued that the Kadmeion and the earlier of the Oedipus Street buildings were similarly aligned, and therefore part of the same architectural complex, viz the Old Palace, (which, for the sake of the argument we will temporarily concede) he proceeds to argue that because his earlier building was probably destroyed in LH IIIA2 (the evidence for which is not entirely without difficulty), therefore the Kadmeion was destroyed at the same time. This view involves a significant *non sequitur*. Even supposing the two structures were *built* at the same time, there is no necessary reason for supposing their destructions were simultaneous. There is one quite good reason, however, for suggesting they were destroyed at different times. The Oedipus Street complex was built over after its destruction, within the Mycenaean period. The Kadmeion was not, suggesting that, no matter when it was built, it could have lasted in occupation until the general destruction and abandonment of Mycenaean Thebes; if so, it was probably destroyed at the same time as the later complex on the Oedipus Street site. This is just as plausible an argument for the inter-relationships of the Kadmeion and the Oedipus Street as that put forward by Symeonoglou. The lesson is that the really compelling arguments for the date of a context must be based upon the character of the material of which that context is composed. So far, the most sustained effort at dating the Kadmeion context is that made by Raison.[123] He illustrates examples of the undecorated pottery found by Keramopoulos, including kylikes, angular kylikes with one handle, angular shallow bowls, conical cups and a dipper. This material seems consistent with a date in LH IIIA2, but could easily be later, and belong with LH IIIB. He also considered the very fragmentary decorated table ware[124] said to have been found in the Kadmeion. This evidence has never been very satisfactory; three fragments Raison illustrates are certainly of LH IIIA2 type, but their association with the destruction context seems doubtful.[125]

The Theban ISJs were only part of a larger collection of SJs found in the ruined Kadmeion. Among the uninscribed jars were at least ten decorated with a displayed octopus on shoulders and belly[126] which bear a striking resemblance to storage SJs with the same type of decoration that forms one of the best-known categories of "Re-occupation" pottery from Knossos, datable to LM IIIB.[127] While a more thorough-going investigation of the chronological relationship of these two groups of decorated SJs is obviously called for, we submit that their presence in the Kadmeion group is an argument in favour of a lower rather than a higher date for the group. On balance, we are in general inclined to support a low date, within the 13th century BC.

[123] *VIP* 46ff.

[124] *VIP* pl xxxviii.

[125] *VIP* 52, note 206.

[126] Nos 891-92, 894-96, 898, 910, 913, 925-26, *VIP* plates, VII, XVIII-XXIV, XXXVI.

[127] See, for example, Boardman *On the Knossos Tablets* 72ff; Popham, *Last Days of the Palace at Knossos* (London, 1964), pls 3, 4; Popham, 'Notes from Knossos, Part I' in *BSA* 72 (1977) 185-196, especially 189 and pl 27, c-d.

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Dating of the other ISJs

It is important to review the contextual information for *all* the ISJs, since any detectable tendency towards a higher or a lower date for the non-Theban material to some extent influences our attitude to Thebes itself. There are two fragments to notice in Thebes in addition to the Kadmeion group.

One, TH Z 975, was found by Th Spyropoulos in 1968 in the investigation of the Mycenaean building remains at the Dourrou plot near the Cathedral. The circumstances of discovery are not entirely clear, though reference is made to LH IIIB pottery. A good many fragments of fresco were found at the same time.[128] The second is a light on dark ISJ fragment from the Oedipus Street site published by Symeonoglou[129] from the destruction level of Room B, which he places at the end of LH IIIB1. The majority of material he illustrates is certainly no earlier than this; some of the fragments would not look out of place in a LH IIIB2 assemblage.

What about the date of the contexts in which the ISJs have been found elsewhere? Close to Thebes is the singleton from Orchomenos. Sacconi accepts Mylonas' date of LH IIIB for the piece, but as its context is unknown, little reliance should be put upon it. Next comes Kreusis; the evidence is quite inconclusive since the ISJ fragment seems to have been collected on the surface together with EH, MH, LH IIIA2 and LH IIIB pottery.[130] The context of the Eleusis jar, **44**, found by Kourouniotis below the NE angle of the Little Propylaea, has been studied very carefully by G Mylonas[131] who dated it to the late 13th century BC.[132] Further south, at Mycenae, the material is much scattered about the site and requires consideration piecemeal. The most important piece, **45** = MY Z 202, was found at the Poros Wall in 1952; MY Z 203, a fragment, not analysed by us, was found in the same area. Lord William Taylour dated the context of **45** to LH III; Raison prefers to put these in LH IIIB, though his arguments are not very strong.[133] The second nearly complete Mycenae ISJ, MY Z 664, was found by N. Verdelis in the destruction of the West House, which dates the context to the end of LH IIIB1. Of the fragments, MY Z 206 comes from the House of Columns, its context dated to LH IIIB by G Mylonas. MY Z 714 (= **48**) belongs to the NE extension of the acropolis, where it was found by Mylonas in 1965; he has proposed a date near the end of LH IIIB for the context. MY Z 713 (= **47**) and MY Z 714 (= **49**) were found in the Citadel House, and have been dated to LH IIIB by Lord William Taylour and by K.A. Wardle. **50**, very recently found by Mylonas near the Cult Centre, came from a LH IIIB2 context. For Mycenae, then,the ISJ contexts seem all to be within LH IIIB.

The majority of the Tiryns ISJ fragments — 38 out of 41 — were found during the German excavations of 1909 and 1910, and close contextual information is not to be expected. It has been argued by Raison, only fairly convincingly, that all this material found early in the century must have come from LH IIIB contexts. An important fragment, TI Z 29, was found by Gerke in 1972 in soundings outside the citadel, to the west. It, to quote the excavator, ". . . gehört in einem Kontext, der bis auf eine protogeometrische Scherbe rein mykenisch ist".[134] It is unfortunate that no closer date can be offered, for this is a very important piece epigraphically.

On the whole, the evidence of the Tiryns contexts is of limited value though no one seems

[128] *AD* 24 (1969) *Chronika* 180; the text, and comment, is published by Sacconi in Vestigia: *Akten des VI.Internationalen Kongresses für griechische u. lateinische Epigraphik* (Munich, 1972) 417-419. See also *CIV* 54, 173 and plate LIX.

[129] *Kadmeia* 1, 20 and pl 22, fig 33, 9.

[130] *AD* 24 (1969) *Chronika* 185-6. For the site see also *GAC* 250-51, site G.38.

[131] *AJA* XL (1936) 426-431.

[132] See *VIP*, 123, n 7.

[133] *VIP*, 136, with ibid n 51.

[134] *AAA* 7 (1974) fig 13 and pp 22-3; *op. cit.* 'Nouveaux textes en Linéaire B de Tirynthe', 25. See also *Führer durch Tiryns* (1975) 186-189 and fig 91.

seriously to have challenged Raison's proposal that the find circumstances are consistent with a date during LH IIIB.

The context of the single Knossos jar, **73**, is unequivocally LM IIIB; this is important, since it is a complete piece. It was found on debris overlying the floor of Room 1 of the Unexplored Mansion, and had evidently fallen from the upper floor.

In West Crete, the context of the Mameloukas Cave ISJ (not sampled here) seems clearly to have been LM IIIB; it was found with a quantity of complete LM IIIB decorated bases, several of which have been illustrated by Y Tzedakis.[135]

Finally, what of the contexts of the ISJs from Chania itself? The evidence has been summarised by E Hallager in his survey of the material.[136] He argues for an early LM IIIB date, but seems probably to mean by this a date in the first part of the period rather than the last part. While one or two of the items (eg **75** = KH Z 2, **76** = KH Z 3, **78** = KH Z 5) evidently comes from good contexts, a majority are not so easily pinned down. Hallager, in fact, says "The rest of the inscribed sherds were found out of their original contexts, but it is probable that they also date to LM IIIB."

Table 12 summarises the findings of this survey of the dates of the contexts in which ISJs have been found. It will be noted that this includes all ISJs known to us as distinct from those we have sampled. Inscribed vases other than SJs are omitted.

Although the clarity of this evidence is less than ideal—in the case of some of the items of which it is composed, far from ideal—it has a general bias which it would be perverse to ignore. There is no *certain* LH or LM IIIA context for an ISJ that is complete or approximately so. At least five of the complete/nearly complete ISJs come from *certain* LH or LM IIIB contexts—Eleusis, Mycenae (West House and Poros Wall), Knossos and Mameloukas Cave. There is no *certain* LH or LM IIIA context for any of the ISJ fragments. At least nine ISJ fragments came from *certain* LH or LM IIIB contexts—two from Thebes, four from Mycenae, three from Chania.

It was said at the outset that the Theban ISJs are by far the most important group; we have discussed at considerable length the problems inherent in trying to date their context. We do not consider the evidence as it stands permits a definite date, but we feel it should anyway not be earlier than the end of LH IIIA2 (we cannot offer any explanation for Furumark's date in LH IIIA1). A date in LH IIIB is certainly not excluded. We regret that the Tiryns material has in this connection to be ignored; so, too, has much of the Chania material, though final publication of the Chania excavations may allow other pieces to be added to the certain LM IIIB set. Note should, of course, be taken, in using this information, that the contexts of those jars found complete or associated with floors in a destruction horizon are of much greater significance than material from fills. So, for our purposes, Eleusis, Mycenae (West House) and Knossos carry most weight.

In our opinion, the circulation in the Minoan-Mycenaean world of ISJs is a phenomenon very largely of the LH and LM IIIB period. It certainly does not belong to the earlier fourteenth century, and it had not started at the date of the destruction of Knossos early in LM IIIA2. Its focus was West Crete (very probably at Chania); though the circulation was long distance, it was relatively restricted.

Before attempting a final assessment of the historical results of our investigation, it will be convenient to consider the results of analysing ISJs without inscriptions or pot marks. The results are set out below by findspot and by composition types.

135 *AD* 23 (1968) *Chronika* 417-418; *PAE* 1968, 133-138.

136 *Op Ath* XI (1975) 53-86, esp 72-73.

TABLE 12

Site	Ref Nos	Complete No	Frag No	Type of Context	Degree of Reliability	Date Proposed
Thebes (Kadmeion)		29	38	Destruction on floor	Good for majority	LH IIIA21- - LH IIIB1
Thebes (Dourrou)	Z 975	—	1	? Fill	Good	LH IIIB
Thebes (Oedipus St)	—	—	1	Destruction fill	Excellent	LH IIIB1
Orchomenos	Z 1	1	—	?	—	—
Kreusis	Z 1	—	1	Surface	Excellent	LH IIIA2-IIIB
Eleusis	Z 1	1	—	Destruction on floor	Excellent	LH IIIB-? Late
Mycenae (Poros Wall)	Z 202 Z 203	1	1	Uncertain	Excellent	LH IIIB
Mycenae (H of Columns)	Z 206	—	1		Good	LH III
Mycenae (West House)	Z 864	1	—	Destruction on floor	Excellent	LH IIIB1
Mycenae (Citadel House)	Z 713 Z 715	—	2	Destruction fills	Good	LH IIIB
Mycenae NE Acropolis extension	Z 714	—	1	Destruction débris	Excellent	End LH IIIB
Mycenae Cyclopean Terrace oven	Z 716	—	1	Superficial level	Good	Probably LH IIIB
Mycenae	Z 205	—	1	Unknown (Schliemann)	—	—
Tiryns Citadel	Z 1 — 8 + 26 Z 11-25 Z 27, 31, Z 32-50	—	38	Uncertain	Poor	LH IIIB (without strong support)
Tiryns Prophitis Elias Cemetery	Z 9	1	—	Tomb	Fair	LH IIIB
Tiryns Lower Tomb	Z 29 Z 30	—	2	Uncertain	Fair/poor	? LH IIIB
Knossos	2	1	—	Destruction débris	Excellent	LM IIIB
Mameloukas	1	—	1	Cave votive deposit	Excellent	LM IIIB
Chania	Z 2, 3, Z 5	—	3	Occupation deposits	Good	LM IIIB1
	Z 1, 4, Z 6-14	—	12	Occupation deposits or superficial levels	Poor	LM IIIB by analogy
		35	104			

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Findspot	Thebes/Knossos	Probably Locally made	West Crete	Uncertain
Thebes	**90***☆, **91***☆, **92***☆, **93***☆, **94***	—	—	—
Mycenae	—	**96***, **97***, **99****, **104***, **106***	**95***, **98***, **100***, **101****, **102****, **103****, **105***	—
Sparta	—	—	**107***, **108**	—

*Dark on light **Light on dark ☆Ornament other than Linear

The interest of these results, which point to a much more extensive long-distance trade involving storage SJs, is sufficient to suggest a future expansion of our analytical programme to take account of a very much larger selection of uninscribed jars. It is unfortunate that the "Thebes/Knossos" effect prevents any precise attribution for **90**, **91** and **93**, decorated with the displayed octopus that, as we have seen, is so very reminiscent of those from reoccupation contexts at Knossos.

It is remarkable that seven of the twelve Mycenaean SJs should prove to be of West Cretan origin, in view of the preponderance at Mycenae of locally made vessels among its ISJs. Further interest attaches to the almost uniform West Cretan origins of the SJs decorated in the Light on Dark technique—the only exception being 99, which is in fact an uncanonical piece. In general terms, (and this was hinted at some years ago by Boardman)[137] it seems quite probable that the light on dark technique of decorating ISJs and SJs may be a Cretan indicator.

The Mycenae SJs come from two important goups. The context of those from the House of the Oil Merchant is datable to the end of LH IIIB1. The House of the Wine Merchant, unfortunately, is less clearly dated.[138] The group has yet to be published fully. D. French, however, has remarked upon the similarity of the SJs from the Wine Merchant and those from the Oil Merchant.[139] He also expresses the view that the date of the group must be at the end of LH IIIA, or "LH III A/B". This suggests no more than 50 years between the date of the SJs from the House of the Wine Merchant and those from the House of the Oil Merchant. If this analysis is correct the SJs from the House of the Wine Merchant whose composition is of West Cretan type are the earliest illustration so far on the mainland for the long distance traffic from West Crete to Greece. It will be very interesting to have the full account of the House of the Wine Merchant when it is published.

The Mainland of Greece, Chania and Knossos

How do the results of this latest study of the Theban jars relate to general Aegean problems? Their main effect is to encourage a reappraisal of the interdependence of literate administration centres in Crete and on the Greek mainland. They help to focus attention upon the great importance of the 13th century BC in the development of such literacy. Perhaps they

[137] *On the Knossos Tablets* 76.

[138] Raison faces this problem *VIP* 141, n 92, without coming to a very definite conclusion.

[139] *Notes on Prehistoric Pottery Groups from Central Greece* (Athens, privately published, 1972) 40.

should also encourage questioning of certain cherished beliefs, particularly concerning the period at Knossos when bureaucracy flourished, and the date of the Knossian Linear B archive itself.

In their recent revision of the Thebes tablets,[140] Godart and Sacconi had this to say, "Les problèmes du commentaire abordés par J. Chadwick dans son édition n'ont pas été affrontés ici pas plus que les questions relatives à la chronologie des documents. En ce qui concerne ce dernier point, on peut s'interroger une fois encore sur les différences chronologiques qui, selon les archéologues, séparent ou peuvent séparer tant les textes de Thèbes eux-mêmes, que les documents de Thèbes, Mycènes, Tirynthe, Pylos et Knossos. Peut-être n'est-il pas utile de rappeler à nos collègues archéologues que rien dans la langue et la structure des tablettes ne permet d'affirmer que tel groupe d'archives est antérieur à tel autre et qu'en ce qui concerne l'exégèse des textes et l'analyse de la langue mycénienne le philologue traite de la même manière les tablettes de Thèbes, de Pylos ou de Knossos faisant ainsi comme si elles étaient contemporaines.

"A ce propos, la preuve, désormais irréfutable, que d'autres textes thébains, les vases à inscriptions peintes du Kadmeion, ont une origine crétoise et la certitude que des centres crétois du MR IIIB continuaient à utiliser le linéaire B comme écriture de chancellerie, avaient toujours à leur tête un wanax et commerçaient encore avec les palais d'Eleusis, Mycènes, Tirynthe et Thèbes, ne peuvent qu'apporter de l'eau au moulin de ceux qui considèrent qu'un abîme chronologique de plus de 150 ans peut difficilement séparer la chute de Knossos de la fin des palais continentaux."

The ramifications of the ISJs and their interconnections seem to us to support these remarks. While we can see that the evidence upon which we are relying is less than perfect, and certainty is not attainable, we are nevertheless conscious that the several groups of evidence which have been reviewed interlock so closely that modification or alteration of one element can only be achieved if the other elements are capable of alteration. The link between Knossos and the ISJs is clear from the evidence of place names on Knossian Linear B tablets and the ISJs; that link exists no matter where or when the jars were made. Linear B scholarship locates the places in question in West Crete. OES has now established that West Crete is the most probable place of manufacture for a large majority of the ISJs; the discoveries of actual ISJs at Chania and Mameloukas gives this finding independent credence. One of these, **78**, (= KH Z 5), of West Cretan composition, not only clearly belongs to Raison's "Group of Thebes 876" (all the remaining members of which were found in the Kadmeion deposit) but may even be the work of the same vase-painter/scribe. This fragment comes from a context reliably dated to LM IIIB. Not only does this provide a vivid illustration of the link between Chania and Thebes, but it harmonises with the lower date we have proposed above for the Kadmeion deposit.

The mainstream evidence for Mainland literacy — archives or fragments of archives of Linear B tablets at Mycenae, Tiryns, Thebes and Pylos — dates to the 13th century BC, much of it late in the century. This agrees with evidence from West Crete. With the exception of Knossos, Linear B literacy is a phenomenon of the 13th century BC. According to a majority of Minoan archaeologists, the Linear B tablets of Knossos go where Sir Arthur Evans assigned them — in a great destruction early in the 14th century BC. There have been dissentient views, more strongly voiced among Linear B scholars than among Minoan archaeologists. Nevertheless, Knossos, from the contents of its tablets was intimately involved in the affairs of West Crete. It

[140] L. Godart and A. Sacconi, *Les Tablettes en Linéaire B de Thèbes*, Incunabula Graeca LXXXI (Rome 1978).

has produced one sure scrap of evidence—its own ISJ, no **73**—for the survival within Knossos of Linear B literacy during the 13th century BC. However we look at the evidence, Knossos and Chania must have been using Linear B simultaneously. It remains doubtful whether both were Linear B literate throughout the 14th and 13th centuries BC. If we uphold the conventional date for the Knossos archive, Knossos at least, must have used Linear B for two centuries. It is not as certain that the same would have to be true of Chania; there is, as yet, no sign of Linear B literacy there in the 14th century BC, but such negative evidence means little on its own. A possible interpretation of the Chania ISJ phenomenon might be that the system was introduced by a Knossian "central Government" for the exploitation of a commodity in which Chania specialised. The commodity was packaged in this idiosyncratic fashion on Knossian instructions, and redistributed by Knossos to markets on the Mainland with which it had been long associated (unlike Chania). Such an explanation would considerably reduce the importance of Chania as an administrative centre—even, possibly, eliminate it as a centre of literacy by arguing that the vase-painters/scribes who dealt with the jars were seconded from Knossos. If this kind of explanation were right, it would take Knossos deep into the 13th century BC as a literate administrative centre. The conjecture is improbable; it is far more likely that Chania was responsible for organising the preparation, packing and despatch of its own ISJs. To maintain the conventional explanation intact it could be argued that Knossos was the sole Linear B centre up to the LM IIIA2 destruction, and that Chania then replaced Knossos, not having previously been such a centre herself. This argument, however, appears contrived, and is much weakened by the discovery of **73**, and the knowledge that it was locally made. It also ignores the fact that Chania had already been an administrative centre during LM I.

We have been much impressed (as were Godart and Sacconi in the passage quoted above) by the concentration within the 13th century BC of all but the Knossian Linear B evidence. So long as that concentration was confined to the Mainland it was not difficult to explain the high date for the Knossos archive. But now that Chania is involved, and seen to share in the Mainland's 13th century date for Linear B literacy a new element of doubt is inevitably raised. We consider that the effect of our investigation has been sensibly to weaken the strength of the case that associates the Knossian Linear B archive exclusively with the destruction early in LM IIIA2. The future may show that the agument can be taken still further.

Choice of Material *(See Table 1)*

Although Anna Sacconi's *CIV* is in every way a splendid working tool, note must be made of one or two ways in which her terms of reference do not entirely coincide with those of the present inquiry, whose overriding interest lies in the *stirrup jars* with inscriptions painted before firing. At least three of her pieces (MY Z 712 = our **46**, KN Z 1715 = our **72**, and TI Z 52) are not SJs at all, but fine table ware; whatever may have been the reason for inscribing them, it will have been very different from that which produced the ISJs. From the other side, however, Sacconi omits what she calls "pot-marks", among which are numbered our **11 – 14**, **25**, **35**, **41 – 42**. These are what might be termed "jars inscribed with single symbol inscription", where the symbol frequently (though not invariably) does not belong to the accepted Linear B canon. Such symbols vary in form from the very simple open circle on the shoulder of **35**, which might be dismissed as a slightly unusual ceramic decoration, to the complex sign on the belly of **25**. There is also included here the class of SJs (usually decorated in light on dark) which have a cruciform symbol on the pouring spout (eg no **70**). **89** (= KH Z 16) is very much a borderline case. The fragment was certainly part of a storage SJ, but its single-symbol inscription was not painted but incised before firing the false-neck disc.

Samples of eighty-nine vases and fragments have been analysed, including the several categories described above. Seventy-seven of these satisfy requirements as fully fledged ISJs; nine come under Anna Sacconi's definition of "pot-marks", two are not stirrup jars but fine vases and one's status is uncertain.

Catalogue

A brief note is given of the character of each piece analysed, including details of the state of preservation, technique of decoration (ie. whether "dark on light" or "light on dark"), and location of inscription (whether on false neck, spout, shoulder or belly). A transliteration of each inscription is given, following the readings in *CIV* (for the meaning of the diacritical signs used see *CIV*, 17.)

The numbers in heavy type are the catalogue numbers, a continuous series extending throughout the analysed material. Beside each catalogue number is given the laboratory's sample number, a series peculiar to each site and distinguished by the appropriate site prefix (TH = Thebes, O = Orchomenos, E = Eleusis, MY = Mycenae, TI = Tiryns, KN = Knossos, KH = Khania). Where possible, museum register or excavator's inventory numbers are quoted as a further means of identification.

The catalogue is divided in a number of ways. The major divisions are between (i) inscribed jars (and two inscribed fragments other than SJs), (ii) uninscribed SJs, (iii) control samples. Within (i) and (ii) there is a further, self-explanatory, division by provenance. (iii) is arranged by provenance.

ISJs, as this study has already emphasized, have been the subject of intensive study. It is therefore important that the catalogue should include adequate reference to the major sources. Where appropriate, the catalogue items will include reference to A J Evans (*PM* iv, 739-746), G Pugliese Carratelli (*Mon Ant* XL, 423-610), H W Catling and A Millett (C and M) in *Archaeometry* 8, 3-85 (for Thebes only), J Raison (*VIP*) and A Sacconi (*CIV*). The two concordances will, it is hoped, simplify reference.

Part I Inscribed Vases

1 = TH 1 Inv. Thebes 840
Light on dark. Fragment (shoulder). Shoulder.
ku-ru-zo
Raison TH Z 840; Sacconi TH Z 840.
VIP 112, pl XCIV bottom; *CIV* 122, pl XXV, bottom.

2 = TH 2 Inv. Thebes 841
Light on dark. Complete; recomposed. Shoulder.
ku-ru-zo

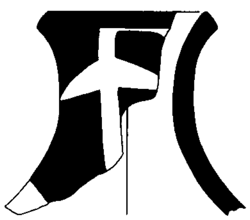

Fig. 7 ISJ fragment from Tiryns, TI **19**.

Evans 15b; Carratelli XIIa; C and M 7; Raison TH Z 841; Sacconi TH Z 841.
PM iv, fig 724b; *Mon Ant* XL, pl XXXVI, top right; *Archaeometry* 8, pl Va-b; *VIP* III, pl XCIII; *CIV* 123, pl XXVI, top.

3 = TH 3 Inv. Thebes 842.
Dark on light. Largely complete; recomposed. Shoulder.
a-do-we
Evans 2; Carratelli IX; C and M 2; Raison TH Z 842; Sacconi TH Z 842.
PM iv 741, fig 724b, no 2; *Mon Ant* XL, pl XXXV; *Archaeometry* 8, pl IIIb; *VIP* 104, pl LXXXII; *CIV* 124, pl XXVI, bottom.

4 = TH 4 Inv. Thebes 844.
Light on dark. Largely complete; recomposed. Shoulder.
Ku-ja-ni (*ku-*56-ni* Raison)
Evans 19; Carratelli XIV; C and M 10; Raison TH Z 844; Sacconi TH Z 844.
PM iv, 741, fig 724b, no 19; *Mon Ant* XL, pl XXXVI, centre right; *Archaeometry* 8, pl VIIIa; *VIP* 117, pl CXVIII; *CIV* 126, pl XXVII, bottom.

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5 = TH 5 Inv. Thebes 849.
Dark on light. Fragmentary; recomposed. Belly.
a-re-zo-me-ne wa-to, re-u-ko-jo
(*a-re-i-me-ne wa-to, re-u-ko-jo* Raison)
Evans 4; Carratelli IV; Raison TH Z 849; Sacconi TH Z 849.
PM iv, 740, fig 724a, no 4; *Mon Ant* XL, pl XXXV, top left; *VIP* 67, pl XLIII; *CIV* 131, pl XXX.

6 = TH 6 Inv. Thebes 850.
Dark on light. Fragmentary; recomposed. Belly.
e-wa-ko[*-ro*], *ka-ma-ti-jo-jo*
Evans 14 + 7; Carratelli V; C and M 15; Raison TH Z 850; Sacconi TH Z 840.
PM iv, 740, fig 724a, no 7 and 741, fig 724b, no 14; *Mont Ant* XL, pl XXXII; *Archaeometry* 8, pl XIa; *VIP* 71, pl XLVIII; *CIV* 132, pl XXXII.

7 = TH 7 Inv. Thebes 851.
Dark on light. Fragmentary; recomposed. Belly.
a-re-zo-me-ne wa-to, re-u-ko-jo[
(*a-re-i-me-ne* Raison)
Evans 3; Carratelli IIIa; Raison TH Z 841; Sacconi TH Z 851.
PM iv 740, fig 724a, no 3; *Mon Ant* XL, pl XXXIII, top left; *VIP* 68, pls XLIV-XLV; *CIV* 133, pls XXXIII-XXXIV.

8 = TH 8 Inv. Thebes 852.
Dark on light. Complete; recomposed. Belly.
a-re-me-ne wa-to, re-u-ko-jo
Evans 2; Carratelli III; C and M 14; Raison TH Z 852; Sacconi TH Z 852.
PM iv, 740, fig 724a, no 2; *Mon Ant* XL, pl XXXIII, 1-4; *Archaeometry* 8, pl Xa-b; *VIP* 69, pl XLVI; *CIV* 134, pls XXXV-XXXVI.

9 = TH 9 Inv. Thebes 854.
Dark on light. Fragmentary; recomposed. Belly.
]*pi-pi, wa-to, su-ro-no*
Evans 6; Carratelli VIa; C and M 17; Raison TH Z 854; Sacconi TH Z 854.
PM iv, 740, fig 724a, no 6; *Mon Ant* XL, pl XXXIV, bottom. *Archaeometry* 8, pl XIIa; *VIP* 65, pl XLI; *CIV* 136, pl XXXIX.

10 = TH 10 Inv. Thebes 855.
Dark on light. Fragmentary; recomposed. Belly.
wo-[.]*-du* (*wo?-i-X-da* Raison)
Carratelli XVIII; Raison TH Z 855; Sacconi TH Z 855.
Mon Ant XL, pl XXXVII, bottom; *VIP* 79, pl LII; *CIV* 137, pl XL, top.

11 = TH 11 Inv. Thebes 859.
Dark on light. Almost complete; recomposed. Belly.
X (? *Ka*)
Raison TH Z 859.
VIP 92, pl LXIII.

12 = TH 12 Inv. Thebes 860.
Dark on light. Fragmentary (full section); recomposed. Belly.
Ka
Raison TH Z 860.
VIP 91, pl LX.

13 = TH 13 Inv. Thebes 861.
Dark on light. Almost complete; recomposed. Belly.
X (? *ka*)
Carratelli XIX; C and M 20; Raison TH Z 861. *Mon Ant* XL, pl XXXVIII top right; *Archaeometry* 8, pl XIIIb; *VIP* 92, pl LXII.

14 = TH 14 Inv. Thebes 862.
Dark on light. Almost complete; recomposed. Belly.
X (?*Ka*)
Evans 24b; Carratelli XIX; C and M 19; Raison TH Z 862.
PM iv, 743, fig 727, no 24b; *Mon Ant* XL, pl XXXVIII, top left; *Archaeometry* 8, pl XIIIa; *VIP* 93, pl LXIV.

15 = TH 15 Inv. Thebes 863.
Dark on light. Almost complete; recomposed. Shoulder.
a-nu-to
Evans 10; Carratelli X; C and M 5; Raison TH Z 863; Sacconi TH Z 863.
PM iv, 741, fig 724b:10; *Mon Ant* XL, pl XXXV; *Archaeometry* 8, pl IVa; *VIP* 105, pls LXXXIII-LXXXIV; *CIV* 141, pl XLII.

16 = TH 16 Inv. Thebes 864.
Dark on light. Almost complete; recomposed. Shoulder.
a-nu-to
Evans 10; Carratelli X; C and M 6; Raison TH Z 864; Sacconi TH Z 864.
Archaeometry 8, pl IVb; *VIP* 106, pl LXXXV-LXXXVI top; *CIV* 142, pl XLII bottom.

17 = TH 17 Inv. Thebes 865.
Dark on light. Fragment; recomposed. Shoulder.
a-nu-to
Carratelli Xa; Raison TH Z 865; Sacconi TH Z 865.
VIP 107, pl LXXXVI, bottom; *CIV* 143, pl XLIII, top.

18 = TH 18 Inv. Thebes 866.
Dark on light. Complete section; recomposed. Shoulder.
i-ru
Evans 18; Carratelli XVa; Raison TH Z 866; Sacconi TH Z 866.
PM iv, 741, fig 724b, no 18; *Mon Ant* XL 607, fig 252 XV a; *VIP* 89, pl LVIII; *CIV* 144, pl XLIII, bottom.

19 = TH 19 Inv. Thebes 867.
Dark on light. Complete; recomposed. Shoulder.
i-ru
Evans 17; Carratelli XV; Raison TH Z 867; Sacconi TH Z 867.
PM iv 741, fig 724b, no 17; *Mon Ant* XL, pl XXXVII, top left; *VIP* 88, pl LVIII; *CIV* 144, pl XLIV, top.

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20 = TH 20 Inv. Thebes 868.
Dark on light. Complete section; recomposed. Belly (with deep wavy band).
ru-i
Carratelli XVb; Raison TH Z 868; Sacconi TH Z 868.
Mon Ant XL, pl XXXVII, top right; *VIP* 90, pl LIX; *CIV* 145, pl XLIV, bottom.

21 = TH 21 Inv. Thebes 869.
Dark on light. Almost complete; recomposed. Shoulder.
ta-de-so
Evans 13; Carratelli VIII; Raison TH Z 869; Sacconi TH Z 869.
PM iv, 741, fig 724b, no 13; *Mon Ant* XL, pl XXXV, centre; *VIP* 100, pl LXXV-LXXVI; *CIV* 146, pl XLV, top.

22 = TH 22 Inv. Thebes 870.
Dark on light. Fragmentary; much lost; recomposed. Shoulder.
]*de-so* (= *ta-*22*]*de-so* or *ta-*]*de-so*)
Raison TH Z 870; Sacconi Th Z 870.
VIP 99, pl LXXIV, bottom; *CIV* 147, pl XLV, bottom.

23 = TH 23 Inv. Thebes 871.
Dark on light. Fairly complete; recomposed. Shoulder.
*ta-*22-de-so*
Raison TH Z 871; Sacconi TH Z 871.
VIP 98, pl LXXIII; *CIV* 148, pl XLVI, top.

24 = TH 24 Inv. Thebes 872.
Dark on light. Fragment (shoulder) recomposed. Shoulder.
ta-]**22-de-so*
Raison TH Z 872; Sacconi TH Z 872.
VIP 99, pl LXXIV, top; *CIV* 149, pl XLVI, bottom.

25 = TH 25 Inv. Thebes 873.
Dark on light. Fairly complete; recomposed. Belly.
X
Evans 239; Carratelli XXI; C and M 24; Raison TH Z 873.
PM iv, 743, fig 727; *Mon Ant* XL, pl XXXVIII, centre left; *Archaeometry* 8, pl XVa; *VIP* 94, pl LXV, right.

26 = TH 26 Inv. Thebes 876.
Dark on light. Fragment (false neck and shoulder). Shoulder.
*ta-*22-de-so*
Evans 12; Carratelli VII; Raison TH Z 876; Raison TH Z 876; Sacconi TH Z 876.
PM iv, 741, fig 724b; *Mon Ant* XL, pl XXXV, top right; *VIP* 97, pl LXXII; *CIV* 150, pl XLVII, top.

27 = TH 27 Inv. Thebes 877.
Dark on light. Fragment. Belly.
ti-tu[
Evans 20; Carratelli XVI; Raison TH Z 877; Sacconi TH Z 877.
PM iv, 741, 724b; *Mon Ant* XL, pl XXXVII, centre; *VIP* 78, pl LII, bottom; *CIV* 151, pl XLVII, bottom.

28 = TH 28 Inv. Thebes 878.
Dark on light. Fragment (belly). Belly.
wa-] *to, su*[*-ro* ± *no* [
Raison TH Z 878; Sacconi TH Z 878.
VIP 66, pl XLII, top; *CIV* 152, pl XLVIII, top.

29 = TH 29 Inv. Thebes 879.
Light on dark. Fragment (shoulder and belly). Shoulder.
Ku]*ru-zo*
Raison TH Z 879; Sacconi TH Z 879.
VIP 113, pl XCV, top; *CIV* 153, pl XLVIII, bottom.

30 = TH 30 Inv. Thebes 880.
Dark on light. Fragment (belly and base). Belly.
]*ni-jo-jo*[
Evans 8; Carratelli XIII; Raison TH Z 880; Sacconi TH Z 880.
PM iv, 740, fig 724a, no 8; *Mon Ant* XL, pl XXXVI; *VIP* 75, pl XLIX; *CIV* 154, pl XLIX, top.

31 = TH 31 Inv. Thebes 881.
Light on dark. Fragment (shoulder) recomposed. Shoulder.
]*ni*
Raison TH Z 881; Sacconi TH Z 881.
VIP 117, pl XCVI, bottom; *CIV* 155, pl XLIX, bottom.

32 = TH 32 Inv. Thebes 882.
Dark on light. Non-joining belly fragments. Belly.
]*-ne*[*wa-*]*to*[ ] *re-u-ko-jo*[
Raison TH Z 882; Sacconi TH Z 882.
VIP 70; pl XLVII; *CIV* 156, pl L, top.

33 = TH 33 Inv. Thebes 883.
Dark on light. Fragment (belly). Belly.
e-wa-ko[*-ro*
Carratelli V; Raison TH Z 883; Sacconi TH Z 883.
Mon Ant XL, pl XXXII; *VIP* 73, pl XLVII, bottom; *CIV* 157, pl L, bottom.

34 = TH 34 Inv. Thebes 884a.
Dark on light. Fragment (belly). Belly.
e-wa]*-ko-ro*
Carratelli V; Raison TH Z 884a; Sacconi TH Z 884a.
Mon Ant XL, pl XXXII; *VIP* 73, pl XLVII, centre; *CIV* 158, pl LI, top left.

35 = TH 35 Inv. Thebes 921.
Dark on light. Almost complete; recomposed. Shoulder.
X
C and M 21.
Archaeometry 8, pl XIVa.

36 = TH 36 Inv. Thebes 958.
Dark on light. Fragment (shoulder). Shoulder.
]e[
Raison TH Z 958; Sacconi TH Z 958.
VIP 83, pl LV, top left; *CIV* 161. pl LII, top left.

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37 = TH 37 Inv. Thebes 960.
Light on dark. Fragment (shoulder). Shoulder.
ku-]ru-zo
Raison TH Z 960; Sacconi TH Z 960.
VIP 115, pl LXXXVI, top right; *CIV* 162, pl LII, bottom.

38 = TH 38 Inv. Thebes 961.
Dark on light. Fragment (shoulder). Shoulder.
a-]nu-to
Raison TH Z 961; Sacconi TH Z 961.
VIP 108, pl LXXXVII, top left; *CIV* 162, pl LIII, top.

39 = TH 39 Inv. Thebes 962.
Dark on light. Fragment (belly). Belly.
]jo
Raison TH Z 962; Sacconi TH Z 962.
VIP 76, pl L top; *CIV* 163, pl LIII, bottom.

40 = TH 40 Inv. Thebes 966.
Dark on light. Fragment (shoulder). Shoulder.
]wa-wo[
Raison TH Z 966; Sacconi TH Z 966.
VIP 84, pl LV, bottom left; *CIV* 165, pl LV, bottom right.

41 = TH 41 Inv. Thebes 967.
Dark on light. Fragment — ? belly. ? Belly.
]a[-?]wa[
Raison TH Z 967.
VIP 81, pl LII, centre.

42 = TH 42 Inv. Thebes 973.
Dark on light. Small fragment (? belly). ? Belly.
]ka[
Raison TH Z 973.
VIP 85, pl LV, bottom right.

43 = OR 1 Inv. Athens 5851.
Orchomenos, excavations of Furtwängler and Bulk 1903.
Dark on light. Almost complete and intact (spout lost). Belly.
ti-sa-ri-[-]
Raison OR Sacconi ORZ1
PM iv, 739, fig 723; *Mon Ant* XL, pl XL, bottom right; *VIP* 119, pl XCIX; *CIV* 119, pl XXIII.

44 = EL 1 Inv. Eleusis No ?.
Below NE angle of the little propylaea — Kourouniotis 1933.
Dark on light. Complete; partly recomposed. Shoulder.
.1 *da-*22-to*
.2 *da-pu*$_2$*-ra-zo, wa,*
Raison EL ; Sacconi EZ 21.
PM iv, suppl pl LXIX a-b; *Mon Ant* XL, bottom left; *VIP* 124, pl c; *CIV* 113, pl XXI.

45 = MY 1 Inv. Athens 7628.
Mycenae, Poros Wall (Wace 1952).
Dark on light. Complete section. Belly.
]e-ra, ka-ta-ro
Raison MY Z 202; Sacconi MY Z 202.
BSA 48 (1953) pl VIIIa; *VIP* 144, pl CI, top; *CIV* 69, pl 1.

46 = MY 2 Inv. Nauplia 13886.
Cup. Mycenae, Cyclopean Wall, Room TC — Mylonas, 1962.
Dark on light. Fragment. Near rim.
pi-ra-ki
Raison MY Z 710; Sacconi MY Z 712.
Kadmos 1 (1962) 95-97, fig; *VIP* 154, *CIV* 72, pl IV bottom.

47 = MY 3 Inv. 62.711 (excavations). Now Nauplia.
Mycenae. Citadel House, Sector ' 12. Taylour-Papadimitriou (1962).
Dark on light. Small fragment (belly). Belly.
.a]*ma-pu[*
.b]*ka[*
Raison MY Z 711; Sacconi MY Z 713.
VIP 150, pl C II, bottom; *CIV* 73, pl V, top.

48 = MY 4 Inv. Nauplia 13983.
Mycenae, NE Acropolis extension — Mylonas 1965.
Dark on light. Small fragment. Belly.
]pi-ka[
Raison MY Z 712; Sacconi MY Z 714.
Kadmos 7 (1968), pl I.2; *VIP* 150, ; *CIV* 74, pl V, bottom.

49 = MY 5 Inv. 66.505 (excavations). Now Nauplia.
Mycenae. Citadel House, sector Γ 21. (Taylour-Mylonas, 1966).
Dark on light. Fragment (shoulder); recomposed. Shoulder.
]ra-u-ko
Raison MY Z 713; Sacconi MY Z 715.
BCH 91 (1967) 658f, fig 17; *VIP* 147, pl CII tev; *CIV* 75, pl VI top.

50 = MY 6 Inv. Mycenae excavation storeroom.
Mycenae, from a LH III B2 level between the West wall of the citadel and the Cult Centre (Mylonas excavation, 1975).
Dark on light. Fragment (shoulder) recomposed. Shoulder.
?]ka-ra (Georgiev)
Not in *VIP* or *CIV*.

51 = MY 7 Inv. 50-580 (excavator's). Nauplia (Leonardo storeroom) A J B Wace excavation, Mycenae, 1950.
No details available.

52 = TI 1 Inv. Nauplia 2054
Tiryns Citadel. E stair. Excavation German Institute 1909-1910.
Dark on light. Fragment (handles, mouth and shoulder). Shoulder.
u-pa-ta-ro
Raison TI Z 1; Sacconi TI Z 1.
PM iv, fig 725b; *Mon Ant* XL, pl XXXIX, centre, right; *VIP* 162, pl CIII, top; *CIV* 77, pl VII, top.

53 = TI 2 Inv. Nauplia 4363.
Tiryns Citadel. Excavation German Institute 1909-1910.
Dark on light. Fragment (belly) recomposed. Belly.
]no-di-zo[
Raison TI Z 11; Sacconi TI Z 11.
PM iv, fig 725f; *Mon Ant* XL, pl XXXVIII, bottom left; *VIP* 169, pl CVII, bottom left; *CIV* 86, pl XII, top.

54 = TI 3 Inv. Nauplia. No no.
Tiryns. Excavations of the German Institute 1909-1910.
Dark on light. Small fragment (upper belly). Belly.
]no[
Raison TI Z 19; Sacconi TI Z 19.
Kadmos 1 (1962) 84, fig 3b; *VIP* 174, pl CXb; *CIV* 92, pl XV, bottom right.

55 = TI 4 Inv. Nauplia. No no.
Tiryns Citadel. German Institute excavations 1909-1910.
Dark on light. Nearly complete; recomposed. Shoulder.
a-do-we[
Raison TI Z 24; Sacconi TI Z 24.
PM iv, fig 725e; *Mon Ant* XL, pl XXXIX, top, left; *VIP* 177, pl CXI; *CIV* 95, pl XVI, top.

56 = TI 5 Inv. Nauplia 4361.
Tiryns Citadel. German Institute Excavation 1909 – 1910.
Dark on light. Small fragment. Shoulder.
]u-no]
Sacconi TI Z 34.
CIV 103, pl XIX, centre right.

57 = TI 6 Nauplia. No no.
Tiryns, Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment. ? Belly.
]u
Sacconi TI Z 36.
CIV 104, pl XIX, bottom.

58 = TI 7 Inv. Nauplia. No no.
Tiryns Citadel. German Institute excavation, 1909-1910.
Light on dark. Small fragment. Shoulder.
]ru[
Sacconi TI Z 39.
Kadmos 1, 85, fig 3q; *VIP* pl CX. q; *CIV* 106, pl XX, right.

59 = TI 8 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (neck). Neck.
]no[
Sacconi TI Z (37).
Kadmos 1, 85, fig 30; *VIP* pl CX, o; *CIV* 105, pl XX, top left.

60 = TI 9 Inv. Nauplia, No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (shoulder). Shoulder.
]a-do-we[
Raison TI Z 25; Sacconi TI Z 25.
Kadmos 1, 85, fig 3m; *VIP* 177, pl CX, m; *CIV* 96, pl XVI, bottom.

61 = TI 10 Inv. Nauplia, No number.
Tiryns Citadel. German Institute excavation 1909-1910.
Dark on light. Small fragment (shoulder). Shoulder.
]u-pa-ta[-ro
Raison TI Z 4; Sacconi Z 4.
Kadmos 1, 84, fig 3a; *VIP* 164, pl CXa; *CIV* 80, pl VIII, top right.

62 = TI 11 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (belly). Belly.
]no[
Raison TI Z 18; Sacconi TI Z 18.
Kadmos 1, 84, fig 3c; *VIP* 173, pl CX, c; *CIV* 92, pl XVIII, top left.

63 = TI 12 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (belly). Belly.
]no[
Raison TI Z 17; Sacconi TI Z 17.
Kadmos 1, 85, fig 3i; *VIP* 173, pl CX, i; *CIV* 91, pl XIV, bottom right.

64 = TI 13 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (shoulder). Shoulder.
Indecipherable
Sacconi TI Z 31.
Kadmos 1, 85, fig 3h; *VIP* pl CX, h; *CIV*, 101, pl XIX, top left.

65 = TI 14 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Fragmentary (body); recomposed. Belly.
no-di[-zo
Raison TI Z 15; Sacconi TI Z 15.
VIP 172, pl CIX; *CIV* 90, pl XIV, top.

66 = TI 15 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Light on dark. Small fragment. ? Belly.
]ja-ti[
Sacconi TI Z 49.
CIV 108.

67 = TI 16 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Fragment (handle and shoulder). Shoulder.
A_3-ta-[
Raison TI Z 6; :Sacconi TI Z 6.
Kadmos 1, 84, fig 2b; *VIP* 165, pl CV, top; *CIV* 82, pl IX, top.

68 = TI 17 Inv. Nauplia. No number.
Tiryns Citadel. German Institute excavation, 1909-1910.
Dark on light. Small fragment (belly). Belly.
]no[
Raison TI Z 21; Sacconi TI Z 21.
Kadmos 1, 85, fig 3n; *VIP* 175, pl CX, n; *CIV* 93, pl XV, centre right.

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69 = TI 18 Inv. LXI 41/15 XIVa G61 (Excavations).
Tiryns, Unterberg. German Institute excavation 1978?
Dark on light. Fragment. ? Shoulder.

AA 1979, 454, fig 3;

70 = TI 19 Inv. LXI 41/24 XIVa 14.11 (Excavations).
Tiryns Unterberg. German Institute excavation, 1978 (Kilian).
Light on dark. Spout and shoulder. Spout.
X
Unpublished. Here, p. 104, Fig. 7.[141]

71 = TI 20 ? Whereabouts + Nauplia. No number.
Two joining fragments from the Tiryns Unterberg, one now lost*, the second from J Schafer's 1968 excavation.
Dark on light. False neck disc* + one handle. False neck disc.
]*du-ne-u*
Sacconi TI Z 30.
AAA VI (1973) 306-9; *CIV* 100, pl XVIII, bottom.
*Said to be in an anonymous private collection.

72 = KN 1 Inv. Herakleion 2632.
Knossos, Palace excavations, 1902. Court of the distaffs.
Cup Dark on light. Fragment (rim/handle). Lip.
[.]-**89-a*
Raison KN Z 1715; Sacconi KN Z 1715.
BSA 8 (1901-1902) 67, fig 33; *PM* IV, 738-9, fig 722; *VIP* 183, n.5 and references, pls CXVI-CXVIII; *CIV*.

73 = KN 2 Inv. Herakleion 21391
Knossos, Unexplored Mansion, Room 1. Popham/Sackett excavation, 1968.
From a LM IIIB context.
Dark on light. Complete; recomposed. Shoulder.
wi-na-jo
Sacconi KN Z 1716.
Kadmos 8 (1969) 43-45, pl 1c; *AR* 1972-73, 60-61, figs 45-46; *CIV* 178, pl LX, bottom.

74 = KH 1 Inv. Khania.
Khania, Kastelli. Greek excavations 1964 (Tzedakis).
Context ? LM IIIB.
Dark on light. Small fragment (shoulder). Shoulder.
ka-ru-ka[
Sacconi KH Z 1.
Op Ath XI (1975) 64, fig 16, pl V, top; *CIV* 179. pl LXI, top.

75 = KH 2 Inv. Khania.
Khania, Kastelli, Greek excavations, 1966 (Tzedakis).
From an early LM IIIB context.
Dark on light. Fragments (shoulder) non-joining. Shoulder.
]*ma-i-jo*
Sacconi KH Z 2.
Kadmos VI (1967) 106-9, pl 1b; *Op Ath* XI (1975) 65, fig 17, pl VI, top; *CIV* 180, pl LXI, bottom.

[141] We are indebted to Dr K. Kilian for this drawing.

76 = KH 3 Inv. Khania.
Khania, Kastelli. Greek excavations, 1966 (Tzedakis). LM IIIB context.
Dark on light. Small fragment. ? Whence.
]*ma-di-jo*[
Sacconi KH Z 3.
Kadmos 6, 106-9, pl 1a; *Op Ath* XI, 66, fig 18, pl Vb; *CIV* 180 pl LXII, top.

77 = KH 4 Inv. Khania.
Khania, Kastelli. Greek excavations, 1966 (Tzedakis).
? LM IIIB context.
Dark on light. Small fragment (shoulder). Shoulder.
]*pu-ti*[
Sacconi KH Z 4.
Op Ath XI, 66, fig 19, pl Va; *CIV* 181, pl LXII, bottom.

78 = KH 5 Inv. Khania 3106/19.
Khania Kastelli. Greek excavations, 1966 (Tzedakis).
Dark on light. Small fragment (shoulder). Shoulder.
]*de-so*[
Sacconi TH Z 5.
Op Ath XI, 67, fig 20, pl VIb; *CIV* 181, pl LXIII, top.

79 = KH 6 Inv. Khania.
Khania Kastelli. Greek excavations, 1966 (Tzedakis).
? LM IIIB (not in context).
Dark on light. Small fragment. ? Shoulder.
]*ka*[
Sacconi KH Z 6.
Op Ath XI, 68, fig 21, pl VI, c; *CIV* 182, pl LXIII, bottom.

80 = KH 7 Inv. Khania.
Khania Kastelli. Greek excavations, 1966 (Tzedakis).
? LM IIIB.
Dark on light. Small fragment (false neck and shoulder). Shoulder.
]*to*
Sacconi KH Z 7.
Op Ath XI, 68, fig 22, pl VIIa; *CIV* 183, pl LXIV, top.

81 = KH 8 Inv. Khania.
Khania, Kastelli. Greek excavations, 1966 (Tzedakis).
? LM IIIB.
Dark on light. Small fragment (shoulder). Shoulder.
]-*pa*[
Sacconi KH Z 8.
Op Ath XI, 69, fig 23, pl VIIb; *CIV* 183, pl LXIV, bottom.

82 = KH 9 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations, 1966 (Tzedakis-Styrenius).
Mixed context.
Dark on light. Non-joining fragments. Shoulder.
]*u*-[
Sacconi KH Z 9.
Op Ath XI, 69, fig 24, pl VIII; *CIV* 184, pl LXV.

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83 = KH 10 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations, 1970 (Tzedakis-Styrenius).
Dark on light. Small fragment. ? Belly.
]*pu-ti*[
Sacconi KH Z 10.
Op Ath XI, 69, fig 25, pl 85a; *CIV* 185, pl LXVI, top.

84 = KH 11 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations (Tzedakis-Styrenius). ? Context.
Dark on light. Small fragment (shoulder). Shoulder.
e[
Sacconi KH Z 11.
Op Ath XI, 71, fig 26, pl Xa; *CIV* 186, pl LXVI, bottom.

85 = KH 12 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations (Tzedakis-Styrenius).
Dark on light. Small fragment (shoulder). Shoulder.
]*ta*
Sacconi KH Z 12.
Op Ath XI, 71, fig 27, pl Xb; *CIV* 186, pl LXVII.

86 = KH 13 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations (Tzedakis-Styrenius).
? Context.
Dark on light. Small fragment (false neck disc and handle). False neck disc.
]*pa*[
Sacconi KH Z 13.
Op Ath XI, 72, fig 28, pl Xc; *CIV* 187, pl LXVIII, top left.

87 = KH 14 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations (Tzedakis-Styrenius). ? Context.
Dark on light. Small fragment. ? Shoulder.
]*ka*[
Sacconi KH Z 14.
Op Ath XI, 72, fig 29, pl 86d; *CIV* 187, pl LXVIII, top right.

88 = KH 15 Inv. Khania.
Khania, Kastelli. Greek-Swedish excavations (Tzedakis-Styrenius). ? Context.
Dark on light. Small fragment (shoulder). Shoulder.
]**56*[
Sacconi KH Z 15.
Op Ath XI, 72, fig 30, pl Xe; *CIV* 188, pl LXVIII, bottom.

89 = KH 16 Inv. Khania excavator's no. GSE 76 P1.
Khania, Kastelli. Greek-Swedish excavations, 1976 — Room D.
Context probably LM IIIB1.
Incised inscription on light on dark.
Small fragment (false neck). False neck disc.
wa
Heillager KH Z 16.
AAA IX (1976) 215, fig 3.

Part II Uninscribed Vases

90 = TH 43 Inv. Thebes 891.
Dark on light. Almost complete; recomposed.
Displayed octopus on shoulder. Banded.
Raison TH Z 891.
VIP 38-9, note 143 and pl XXI.

91 = TH 44 Inv. Thebes 913.
Dark on light. Complete. Recomposed.
Displayed octopus on shoulder and belly.
Raison TH Z 913.
VIP 39, note 146, pl XXII, top.

92 = TH 44 Inv. Thebes 924.
Dark on light. Fragmentary; recomposed.
Groups of curved stems on shoulder and belly.
Raison TH Z 924.
VIP 42, note 159, pls XXVIII-XXIX.

93 = TH 46 Inv. Thebes 926.
Dark on light. Largely complete. Recomposed.
Displayed octopus on shoulder and belly.
Raison TH Z 926.
VIP 41, note 151, pl XXVI.

94 = TH 47 Inv. Thebes 943.
Dark on light. Almost complete.
Banded.
Archaeometry 8, 47f, no 22 and pl XIVb.

95 = MY 8 Inv. Nauplia 10942.
Mycenae, House of the Wine Merchant. Wace excavations, 1952.
Context LH IIIA2.
Dark on light. Almost complete; recomposed.
Foliate band on shoulder. Banded body.
BSA 48 (1953) pl 8c.

96 = MY 9 Inv. Nauplia 10994.
Mycenae, House of the Wine Merchant. Wace excavations, 1952.
Context LH IIIA2.
Dark on light.
Banded.

97 = MY 10 Inv. Nauplia 10993.
Mycenae, House of the Wine Merchant, Wace excavations 1952. Context LH IIIA2.
Dark on light.
Banded.

98 = MY 11 Inv. Nauplia 10961.
Mycenae, House of the Wine Merchant, Wace excavations, 1952. Context LH IIIA2.
Dark on light.
Banded.

99 = MY 12 Inv. Nauplia 10967.
Mycenae, House of the Wine Merchant, Wace excavations, 1952.
Light on dark.
Vertical lines: unusual type — stands apart from other light on dark designs.

100 = MY 13 Inv. Nauplia 10995.
Mycenae, House of the Wine Merchant, Wace excavations, 1952.
Light on dark.
Banded; wavy line on shoulders.

101 = MY 14 Inv. Nauplia 10965.
Mycenae, House of the Wine Merchant, Wace excavations, 1952.
Light on dark. Fragmentary; recomposed. Banded. Gross on false neck disc.
VIP 25 (part of note 114), pl X, bottom.

102 = MY 15 Inv. Nauplia 5344.
Mycenae, House of the Oil Merchant, Wace excavations 1950.
Light on dark. Fairly complete; recomposed.
Banded.
Probably among the group illustrated *Mycenae Tablets* II (1958) fig 34.

103 = MY 16 Inv. Nauplia 5347.
Mycenae, House of the Oil Merchant, Wace excavations, 1950. Context LH IIIB.
Light on dark. Fairly complete; recomposed.
Banded.
See *VIP* 130, note 7. Probably among the group *Mycenae Tablets* II, fig 34.

104 = MY 17 Inv. Nauplia 5361.
Mycenae, House of the Oil Merchant, Wace excavations, 1950.
Dark on light. Fairly complete; recomposed.
Banded; curvilinear pattern on belly.
VIP pl XVI, top, and see 130, note 7.

105 = MY 18 Inv. Nauplia 5339.
Mycenae, House of the Oil Merchant, Wace excavations, 1950.
Light on dark. Almost complete; recomposed.
Banded.
VIP 34, note 114. Probably among the group *Mycenae Tablets* II, fig 34.

106 = MY 19 Inv. Nauplia 5359.
Mycenae, House of the Oil Merchant, Wace excavations, 1950.
Dark on light. Fairly complete; recomposed.
Banded. Curvilinear pattern on belly.
BSA 48 (1955) pl 7b and see p 13 *VIP* pl XVI, bottom.

107 = SM 1 Inv. P715 (Excavator's).
Sparta, Menelaion. Mansion 2, reoccupation. (British School excavations, 1973). Context probably LH III B2.
Dark on light. Fragment – false neck, handles and shoulder.
Unpublished.

108 = SM 2 Inv. P. 752 (Excavator's).
Sparta, Menelaion. British School excavations 1974. Grid J.25, in a LH IIIB fill.
(Probably) Dark on light. Fragment – spout.
Unpublished.

Part III Control Samples[142]

A. Thebes Twenty decorated LH IIIB sherds, chiefly fine wares. The majority was found in association with the palace archives. A sample was also analysed from a modern clay brick produced at Tanagra, some 20 kilometres from Thebes.

This control was also used for **43** (Orchomenos), found more than 40 kilometres WNW of Thebes. Preliminary investigation of some Mycenaean pottery found at Orchomenos suggests that its composition closely resembles that of Thebes.

B. Athens Twenty-three fine decorated and coarse ware sherds of LH IIIA-LH IIIC types from the Agora (excavations of the American School).

This material served as a control for **44** (Eleusis), found some fifteen kilometres West of Athens. It is at this stage impractical to attempt to identify archaeologically the *local* Mycenaean pottery of Eleusis.

C. Mycenae Nineteen LH IIIB sherds (mostly decorated fine wares) (from the area of the Lion Gate. Samples have been analysed from raw and fired clay bricks, viz. two fired clay bricks, one each from the brickworks to the North and South-East of Argos; one sample each of raw clay and earth filler components of the brick from the former brickworks; one sample of raw clay from the stream bed below the prehistoric site of Berbati.

This control was also used for **52 – 71** (Tiryns), some fifteen kilometres from Mycenae. A sample was analysed of fired brick from brickworks North of Nauplion, and thus very close to Tiryns.

D. Sparta, Menelaion 46 Mycenaean sherds from the British School excavations 1973-74, consisting of (a) nine undecorated LH IIIB2 kylikes, (b) ten angular shallow bowls and conical cups, LH IIIB2, (c) nine monochrome goblets, LH IIIA1, (d) nine handmade jugs, LH IIIA1, (e) nine decorated LH IIIA1 fragments.

E. Knossos Twenty-four fine and coarse LH IIIB sherds from the excavation of the Unexplored Mansion.

A sample was also analysed of raw clay collected two kilometres South of the Palace.

F. Palaikastro (E. Crete) Twenty-three fine and coarse LM IIIB from the British School's excavations 1964 (M R Popham and L H Sackett).

[142] The control samples were selected to reflect as far as possible a range of fabrics from each site and of a date contemporary with the test samples. The range of sites was restricted, in order to maintain the study within manageable proportions, to those producing test samples, while Palaikastro was included – for obvious reasons – as a 'marker' for east Crete. A small number of samples of raw clay and modern brick were also considered for comparative purposes.

G. Chania (W. Crete)[143] Forty-nine LM III sherds: (a) ten fragments of LM III white ware, (b) nineteen fragments of the semi-lustrous LM I red ware, (c) fourteen fragments of a ware characteristic of LM IIIc, (d) five sherds of LM III brown ware.

A sample was also analysed of grey-coloured raw clay from Agia Marina (vicinity of Chania).[144]

CONCORDANCE 1
(Based on the present catalogue)

Catalogue of Analyses	*Raison*	*Sacconi*	*Other*
1	TH Z 840	TH Z 840	
2	TH Z 841	TH Z 841	C/M 7
3	TH Z 842	TH Z 842	C/M 2
4	TH Z 844	TH Z 844	C/M 10
5	TH Z 849	TH Z 849	
6	TH Z 850	TH Z 850	C/M 15
7	TH Z 851	TH Z 851	
8	TH Z 852	TH Z 852	C/M 14
9	TH Z 854	TH Z 854	C/M 17
10	TH Z 855	TH Z 855	
11	TH Z 859	—	
12	TH Z 860	—	
13	TH Z 861	—	C/M 20
14	TH Z 862	—	C/M 19
15	TH Z 863	TH Z 863	C/M 5
16	TH Z 864	TH Z 864	
17	TH Z 865	TH Z 865	
18	TH Z 866	TH Z 866	
19	TH Z 867	TH Z 867	
20	TH Z 868	TH Z 868	
21	TH Z 869	TH Z 869	
22	TH Z 870	TH Z 870	
23	TH Z 871	TH Z 871	
24	TH Z 872	TH Z 872	
25	TH Z 873	—	C/M 24
26	TH Z 876	TH Z 876	
27	TH Z 877	TH Z 877	
28	TH Z 878	TH Z 878	
29	TH Z 879	TH Z 879	
30	TH Z 880	TH Z 880	
31	TH Z 881	TH Z 881	
32	TH Z 882	TH Z 882	
33	TH Z 883	TH Z 883	
34	TH Z 884a	TH Z 884a	
35	TH Z 921	—	C/M 21
36	TH Z 958	TH Z 958	
37	TH Z 960	TH Z 960	
38	TH Z 961	TH Z 961	
39	TH Z 962	TH Z 962	
40	TH Z 966	TH Z 966	
41	TH Z 967	TH Z 967	
42	TH Z 973	—	
43	OR Z 1	OR Z 1	
44	EL Z 1	EL Z 1	
45	MY Z 202	MY Z 202	
46	MY Z 710	MY Z 712	
47	MY Z 711	MY Z 713	
48	MY Z 712	MY Z 714	
49	MY Z 713	MY Z 715	
50	—	—	MY Z 717 (Georgiev in *Kadmos* 1976) Exc. no. 50.580
51	—	—	
52	TI Z 1	TI Z 1	
53	TI Z 11	TI Z 11	
54	TI Z 19	TI Z 19	
55	TI Z 24	TI Z 24	
56	—	TI Z 34	
57	—	TI Z 36	
58	—	TI Z 39	
59	—	TI Z 37	
60	TI Z 25	TI Z 25	
61	TI Z 4	TI Z 4	
62	TI Z 18	TI Z 18	
63	TI Z 17	TI Z 17	
64	—	TI Z 31	
65	TI Z 15	TI Z 15	
66	—	TI Z 49	
67	TI Z 6	TI Z 6	
68	TI Z 21	TI Z 21	
69	—	—	*AA* 1979, 454, fig 3
70	—	—	Exc. no. LXI 41/15 XIVa G61
71	—	TI Z 30 + fr	
72	KN Z 1715	KN Z 1715	
73	KN Z 1716	KN Z 1716	
74	—	KH Z 1	
75	—	KH Z 2	
76	—	KH Z 3	
77	—	KH Z 4	
78	—	KH Z 5	
79	—	KH Z 6	
80	—	KH Z 7	
81	—	KH Z 8	
82	—	KH Z 9	
83	—	KH Z 10	
84	—	KH Z 11	
85	—	KH Z 12	
86	—	KH Z 13	
87	—	KH Z 14	
88	—	KH Z 15	
89	—	—	*AAA* 9 (1976), 215, fig 3

[143] Additional comments on this material appear in section 5.

[144] We are grateful to Miss J. Moody for collecting this and other clay samples from the Chania region.

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CONCORDANCE 2
(Based on Sacconi Numbers)

Sacconi	Catalogue of analyses
MY Z 202	45
MY Z 712	46
MY Z 713	47
MY Z 714	48
MY Z 715	49
TI Z 1	52
TI Z 4	61
TI Z 6	67
TI Z 11	53
TI Z 15	65
TI Z 17	63
TI Z 18	62
TI Z 19	54
TI Z 21	68
TI Z 24	55
TI Z 25	60
TI Z 30 + fr	71
TI Z 31	64
TI Z 34	56
TI Z 36	57
TI Z 37	59
TI Z 39	58
EL Z 1	44
OR Z 1	43
TH Z 840	1
TH Z 841	2
TH Z 842	3
TH Z 844	4
TH Z 849	5
TH Z 850	6
TH Z 851	7
TH Z 852	8
TH Z 854	9
TH Z 855	10
TH Z 863	15
TH Z 864	16
TH Z 865	17
TH Z 866	18
TH Z 867	19
TH Z 868	20
TH Z 869	21
TH Z 870	22
TH Z 871	23
TH Z 872	24
TH Z 876	26
TH Z 877	27
TH Z 878	28
TH Z 879	29
TH Z 880	30
TH Z 881	31
TH Z 882	32
TH Z 883	33
TH Z 884a	34
TH Z 958	36
TH Z 960	37
TH Z 961	38
TH Z 962	39
TH Z 966	40
TH Z 967	41
KN Z 1715	72
KN Z 1716	73
KH Z 1	74
KH Z 2	75
KH Z 3	76
KH Z 4	77
KH Z 5	78
KH Z 6	79
KH Z 7	80
KH Z 8	81
KH Z 9	82
KH Z 10	83
KH Z 11	84
KH Z 12	85
KH Z 13	86
KH Z 14	87
KH Z 15	88

H W CATLING

J F CHERRY

R E JONES

J T KILLEN

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