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Elemental and Petrographic Analyses of Local and Imported Ceramics from Crusader Acre

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Introduction

Acre was the main port of the Latin Kingdom of Jerusalem during the Crusader period (twelfth–thirteenth centuries CE), and its capital after the establishment of the second Kingdom in 1191. During this period, a large amount of the maritime trade in the eastern Mediterranean was directed to Acre, which served as a transit port. Italian merchants conducted the main part of this trade, with merchandise coming from Europe, the Byzantine Empire and the Muslim and Crusader states in the East. Thus, Acre is a particularly interesting site for the study of material and cultural exchanges between the Levant and the Western and Byzantine worlds.

Since 1991, excavations undertaken by the Israel Antiquities Authority in Acre have yielded many Crusader-period remains. The main excavated site is the Hospitaller compound, built in the twelfth century by the knights of the Order of St. John (Avissar and Stern 1994; 1998; Stern E. 1999; 2001; 2002; 2006). Excavations were also carried out in part of a thirteenth-century wall and moat (Hartal 1997), a residential and commercial area (Syon and Tatcher 2000), and other parts of the Old City (Mesika Plot, excavated by D. Syon in 1994; Stern E. 1997:28–29; 1999). Abundant ceramic material dated to the twelfth and (mainly) thirteenth centuries was uncovered in these excavations and others. The diversity of sources of the ceramic material illustrates the links between the eastern (Byzantium, Cyprus, the Aegean, Christian and Islamic Syria) and western (Italy, southern France, Spain and north Africa) Mediterranean (Stern E.J. 1997; 1999; Pringle 1997; Edelstein and Avissar 1997).

Literature of the time provides little information on pottery production in the Crusader Kingdom. Since the 1980s, archaeological publications have paid greater attention to ceramics that are suspected of having been produced in the Levant due to their distribution (Thalmann 1978; Salamé-Sarkis 1980; Pringle 1984; 1985; 1986; Avissar 1996; Stern E.J. 1997; Avissar and Stern 2005), although some may have reached Cyprus (Megaw and Jones 1983:262) and even Marseilles (Démians d'Archimbaud and Vallauri 2003). However, little is known about their production sites, organization and distribution patterns, or the way these features may have changed with the arrival of Westerners during Frankish rule. The study of Acre as a main coastal Crusader site and a ceramic production site should provide relevant information. The presence among the material excavated in Acre of wasters of a simple, unglazed type of bowls we named "Acre bowls", is evidence of local production. Likewise may be the textual mention of a street of cooking-pot makers in thirteenth-century Acre (Pringle 1986:470). We therefore thought it important to define a new analytical reference group of locally manufactured ceramics in the Crusader period and to investigate the range of these products, within the limitations of our sampling. Data on such a reference group would be useful during further study of the diffusion of locally-produced Crusader-period ceramics.

In our research, we used elemental and petrographic analyses to obtain more precise information regarding the origin of pottery types common in Crusader Acre than can be obtained by typological study alone. Laboratory analyses

have been extensively used to investigate the origin of ceramics, but seldom in the case of medieval wares in the eastern Mediterranean area (see Waksman 2005 for a bibliography until 1998). The pioneer work of Megaw and Jones (1983), with its planned update and extensions by Armstrong and Hatcher (1997), is a notable exception that resulted in the chemical characterization of several categories of mainly late Byzantine wares from attested production centers. Armstrong and Hatcher's study includes three Levantine production sites: Al-Mina near Antioch with its famous widely-exported Port Saint Symeon ware; Tiberias (for its Islamic production; Stern E.J. 1995), and Acre. Analytical studies that specifically focus on medieval wares in the Levant include the early exploratory work of Frierman (1967). But, as far as we know, it was not until Boas (1991; 1994) that chemical and petrographic analyses were extensively applied to medieval pottery (mainly the Crusader period) from the Levant. Boas was primarily concerned with imported wares that he sampled from several sites in the Latin Kingdom of Jerusalem. His attempts to re-classify typological categories led to interesting results, but his tentative conclusions on origins have since been reconsidered (Waksman and von Wartburg 2006, Waksman and François 2004–2005). Goren (1997) proposed possible origins for a selection of Crusader-period wares found in Acre according to petrographic features and, therefore, his study may be considered preliminary and complementary to ours. More recently, medieval ceramics produced in workshops revealed during excavations in Beirut (Waksman 2002; François et al. 2003) and Kinet (Gulf of Iskenderum; Blackman and Redford 2005) were characterized by chemical analysis.

Our program was fairly extensive in the number of samples (145) and focused on two broad categories of ceramics. The first one includes wares typical of Levantine sites in the Crusader period sgraffito, slip-painted, reserved-slip glazed bowls and glazed cooking pots. The second one includes wares belonging to the Zeuxippus Family.

Zeuxippus Ware was first distinguished by Megaw (1968). Extensively referred to in publications, it may be considered one of the best known types of late Byzantine ceramics. This ware has been found in a large area extending from Italy and southern France to the Levant, and from the Black Sea to Egypt (François 1997). However, as more material was published, it became clear that this ware did not come from a single production site and that it had many imitations and derivatives (Armstrong 1992; Spieser 1996:51; Stern E.J. 1997:54–56). As a result of its influence on the decorative repertoire of the thirteenth century (Spieser 1991), the terminology Zeuxippus Ware was extended to Zeuxippus Family (Megaw 1989).

The ability to distinguish between a 'prototype' and 'derived' or related productions is important as it helps prevent confusion within the Zeuxippus Family. Characterization of different productions related to Zeuxippus Ware enables tracing the diffusion of each one. The characteristics may be determined by elemental and petrographic analyses. Waksman (1995) and Waksman and Spieser (1997) used both methods to characterize a 'derived production' manufactured in Pergamon. Boas (1991; 1994) stated, on the basis of chemical analysis, the existence of two compositional groups of high quality Zeuxippus Ware indistinguishable by typology. Attempts to identify the production site(s) of Zeuxippus Ware were made by Megaw, Armstrong and Hatcher (2003). A comprehensive analytical and typological study of Zeuxippus-related wares from several sites in the Mediterranean and Black Sea areas was recently carried out by Waksman and François (2004–2005), with the aim of reconsidering the whole question of their production and diffusion. The present work (see also Waksman et al. 1999; Stern and Waksman 2003) constituted an initial step in this larger project.

TYPOLOGY OF SAMPLED CERAMICS

The pottery samples selected for this study are listed in the index (Appendix 1) and described below.

LOCAL AND REGIONAL WARES

Various types of glazed and unglazed bowls and cooking ware were grouped together in this category, indicated in this study by the prefix ACR. These types are very common in Acre and, therefore, were chosen for analysis. Our assumption was that they were manufactured in or near Acre.

The first group consists of Acre bowls, a simple, probably mass-produced unglazed bowl, which seems unique to Acre. Many such bowls were found in excavations at Acre, mainly in the Hospitaller Compound (Stern E.J. 1997:37–39; Stern and Waksman 2003:168, Fig. 2; Avissar and Stern 2005:82, Fig. 35: 4–6), but also in other sites in Acre (Pringle 1997:138, Fig. 6:10, 11, and unpublished material). They apparently served members of the Order, hospitalized patients, and pilgrims who stayed at the compound before embarking on pilgrimage through the Holy Land. Such bowls were not found in other excavated sites in the Latin Kingdom of Jerusalem except for some rural sites near Acre, such as Ḥorbat ʻUẓa (Stern and Tatcher, forthcoming) and Ḥorbat Manot (Stern E.J. 2001:286, Fig. 6:4–7). Evidence of local production was found in the Hospitaller Compound at Acre in the form of wasters of Acre bowls (Fig. 1).

The second group under study consists of glazed bowls and cooking ware. These wares were considered local because of their fabric (red to red-brown with limestone grits, similar to the Acre bowls) and distribution (mainly the coastal area of northern Israel and southern Lebanon). Vessels of these types were, however, also found in Cyprus at Saranda Kolones, Paphos (Megaw 1971:123–124, Figs. 2:2, 7; 3:5; Rosser 1985:89, Fig. 15, F.3), Kouklia (von Wartburg 1998:147, 156, Figs. 66:29–31; 79:58), and other excavated

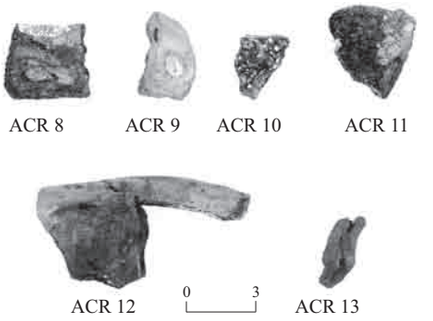


Fig. 1. Acre bowl wasters.

but unpublished sites. They seem to be imported to these sites since they differ from the locally-produced Cypriot glazed bowls and cooking ware (for local Cypriot cooking ware of this period, see von Wartburg 1998:142, 147, Figs. 59:18, 19; 66:32).

Acre Bowls (Figs. 2:1; 3)
The fabric of these bowls is coarse and gritty, the color varies from red 2.5YR 4/8 and yellowish red 5YR 5/6 to brown-dark brown 7.5YR 4/2 and very dark gray 10YR 3/1. The bowls have a light self-slip surface that ranges from white 10YR 8/2 and white 5Y 8/1 to light red 2/5YR 6/6 and light brown 7.5YR 6/4. The typical bowl has a short ledge rim, a hemispherical body, and a flat, string-cut base.

Glazed Bowls
The glazed bowls share the same color and texture of fabric, but differ in typology by the technique of decoration and glaze. Three types were studied.

Sgraf□to (Figs. 2:2; 4).□ The fabric color of this type of bowl is yellowish red 5YR 5/6–5/8 and the main feature is the gritty interior surface. The interior slip of the vessel is very thin and does not always entirely cover it. The glaze appears in different shades of the main green or yellow color. The bowls usually have a very short ledge rim and a carinated shoulder, but may have a simple rim. Very small bowls may have a broad ledge rim. The base is a low, wide ring. The sgraffito decoration of very

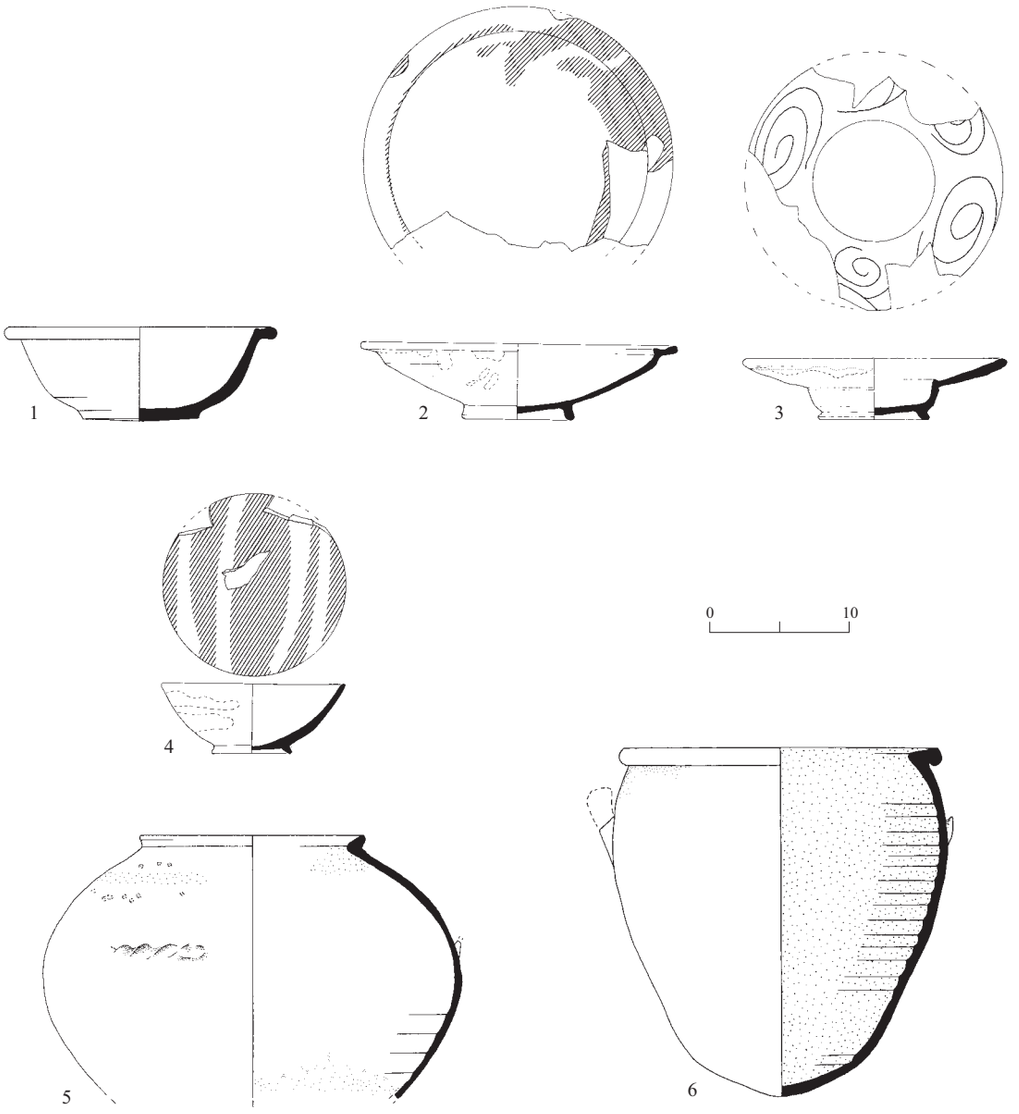


Fig. 2. Typical local and regional ware.

No.	Type	License/Permit No.	Locus	Basket
1	Acre bowl*	G-52/93	16006	160503/5
2	Glazed bowl (sgraffito)*	A-2244	723	3227/4
3	Glazed bowl (reserved-slip)	see ACR115, Appendix 1		
4	Glazed bowl (slip-painted)	see ACR109, Appendix 1		
5	Cooking pot (thin-walled)*	G-102/92	13032	130385/2
6	Cooking pot (thick-walled)*	G-102/92	12025	120454/2

* Not examined in this study

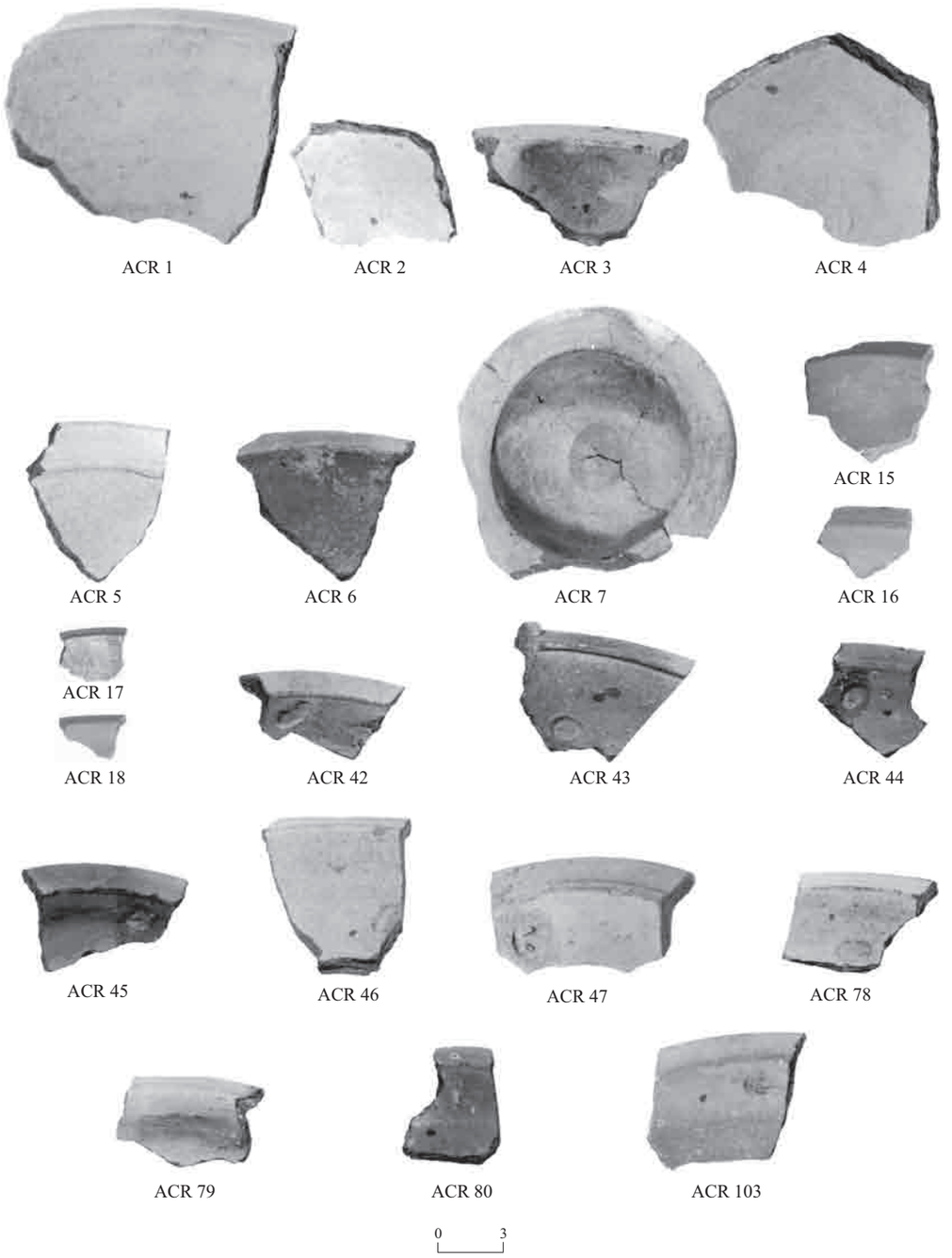


Fig. 3. Acre bowls.

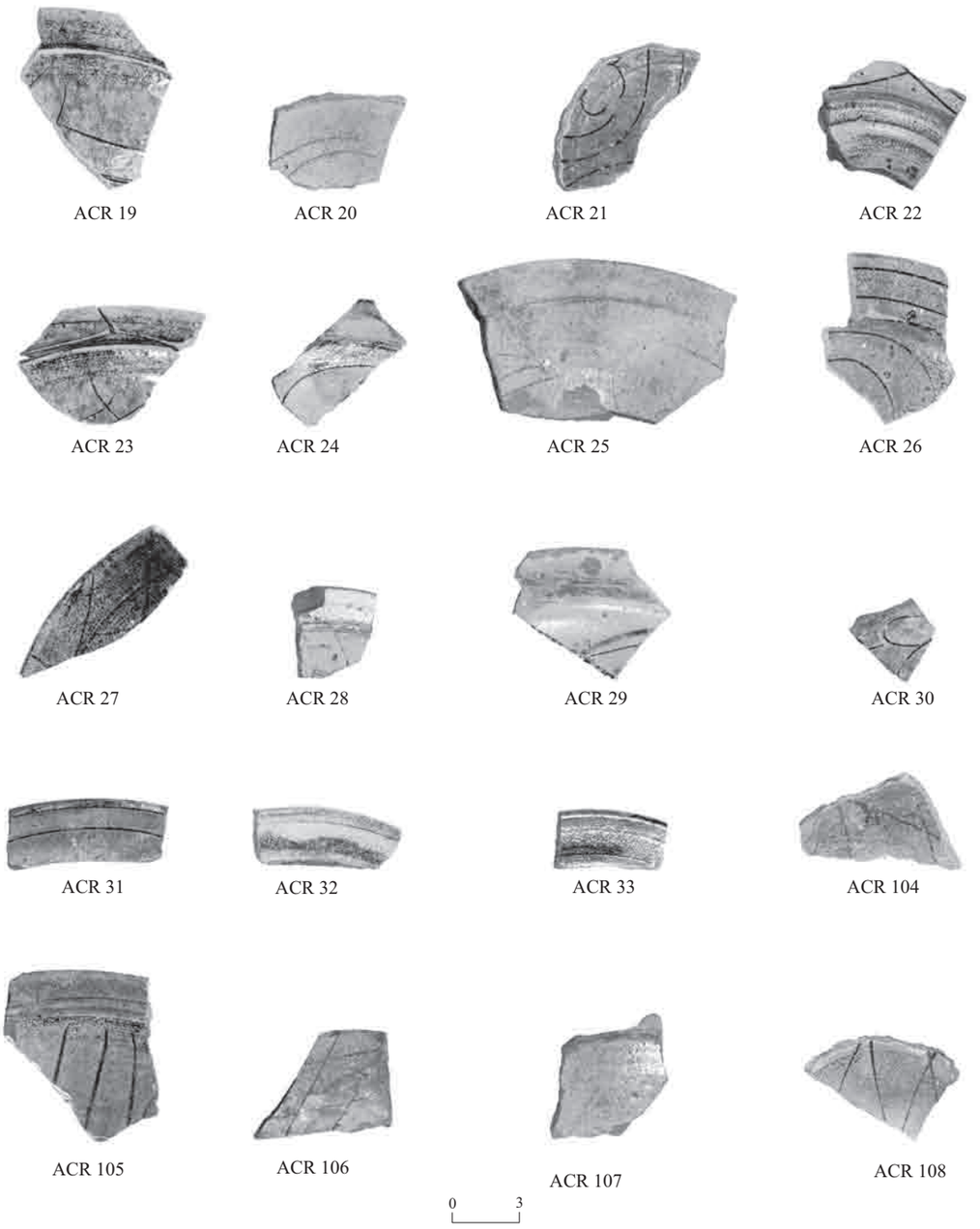


Fig. 4. Glazed bowls (sgraffito).

simple geometric designs was applied with a fine instrument (Stern and Waksman 2003:170–171, Fig. 5: top and left bowls; Avissar and Stern 2005:8, Fig. 2, Pl. II:1–3).

Bowls of this type, usually dated to the end of the twelfth and beginning of the thirteenth centuries, were found at Tell ʻArqa (Thalmann 1978: Figs. 33:6–11; 34:1–14; 35:5–9), Tripoli (Salamé-Sarkis 1980:190–191, Fig. 31:73, 64; Pls. LIX:1; LXXII:9), Beirut (El-Masri 1998: 109, Fig. 8:1, 2), Acre (Stern E.J. 1997:45, Fig. 6:49; unpublished material), Ḥorbat ʻUẓa (Ben-Tor 1966: Fig. 12:6; Stern and Tatcher, forthcoming), Tel Yoqneʻam (Avissar 1996:90–93, Types 34–37, Fig. XIII.22–25), Caesarea (Pringle 1985:177, 183, Figs. 3:12–15; 7:40, 44, 45; 8:46; Arnon 1999:227, Fig. 11:n, o), and Jerusalem (Tushingham 1985:143, Fig. 39:41).

Reserved-Slip (Figs. 2:3; 5). This type is similar to sgraffito in vessel shape but the fabric is slightly different, red 2.5YR 5/6–5/8, the glaze is glossier, and the decoration is executed in the reserved-slip technique. White slip is applied to part of the interior, in a non-orderly way, on the leather-hard body. The bowl is biscuit fired and then the glaze applied. After refiring, the slipped part appears in the color of the glaze and the background is a few shades darker. Usually the glaze is yellow, sometimes with green splashes on various parts of the vessel. The typical bowl is shallow with a short ledge rim and a low ring base (Stern and Waksman 2003:170–171, Fig. 5: middle right and center bowls; Avissar and Stern 2005:22, Fig. 8:1, 2, Pl. VI:8).

Dated to the thirteenth century, bowls of this type are known only from coastal sites and were found at Caesarea (Pringle 1985:179, Fig. 4:22–25; Arnon 1999:227, Fig. 11:k, m).

Slip-Painted (Figs. 2:4; 6). This type has fabric (red 2.5YR 4/6–4/8–5/6) similar to the previous types, but the shapes of the vessels are slightly different. The bowls are hemispherical with simple rims or carinated with ledge rims, some of them very large. The base is a low ring, smaller in diameter than that of the previous types. The glaze seems to be of a lower quality, is transparent in color, and, in most cases, was not preserved. The decoration was produced in a similar manner as the reserved slip, but here the slip was applied with a brush painting a design on the interior of the bowl. The slip painted designs usually consist of broad, straight, intersecting lines. Circles also appear, but are more rare (Stern and Waksman 2003:170–171, Fig. 5: bottom; Avissar and Stern 2005:19–20, Fig. 7:9–11).

Similar bowls were found at Tell ʻArqa (Thalmann 1978:25, Fig. 33:2; Hakimian and Salamé-Sarkis 1980:19–20, Fig. 10:2; Pl. V.I), Acre (Stern E.J. 1997:47–48, Fig. 7:64–66, and unpublished material), Ḥorbat ʻUẓa (Stern and Tatcher, forthcoming), and Caesarea (Pringle 1985:179–183, Fig. 5:26–29; Arnon 1999:227, Fig. 10:k–l).

Cooking Ware

The cooking wares sampled in this study consist of cooking pots only. The cooking pots were usually found with baking dishes of the same fabric, but these were not analyzed due to the limited number of vessels that we could handle. The two main types of cooking pots represented here seem to differ chronologically. Thin-walled types date to the twelfth century and seem to continue the Early Islamic shapes typical of this area (Figs. 2:5; 7). Thick-walled types date to the thirteenth century (Figs. 2:6; 8). Both types have globular bodies, strap handles, and vertical, everted, or molded rims. The thin-walled pots are of a fine hard metallic fabric and have a thick dark glaze that is usually concentrated on the interior of the base with splashes on the exterior of the shoulder. The thick-walled cooking pots are usually of a coarse and sandy fabric with an orange glaze on the entire interior including the rim. Both fabric groups are the same color, ranging between red 10R 4/6–4/8 and 2.5YR 4/6–4/8, and have the same temper with small white grits (Stern and Waksman 2003:169–170, Fig. 3; Avissar and Stern 2005:91–92, 96–97, Figs. 39:1–8; 41:1–3; Pls. XXVI:1–3; XXVII:1).

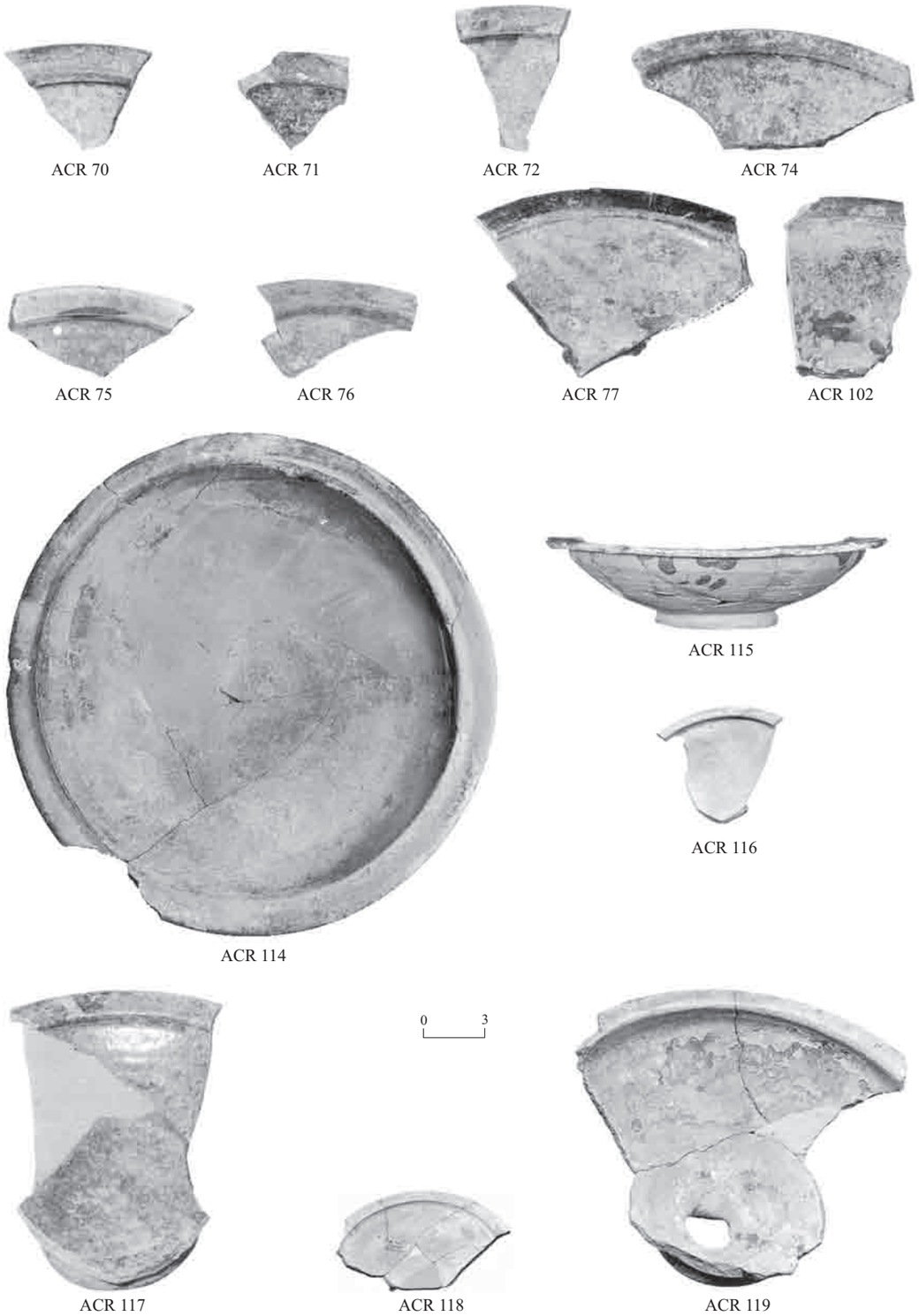


Fig. 5. Glazed bowls (reserved-slip).

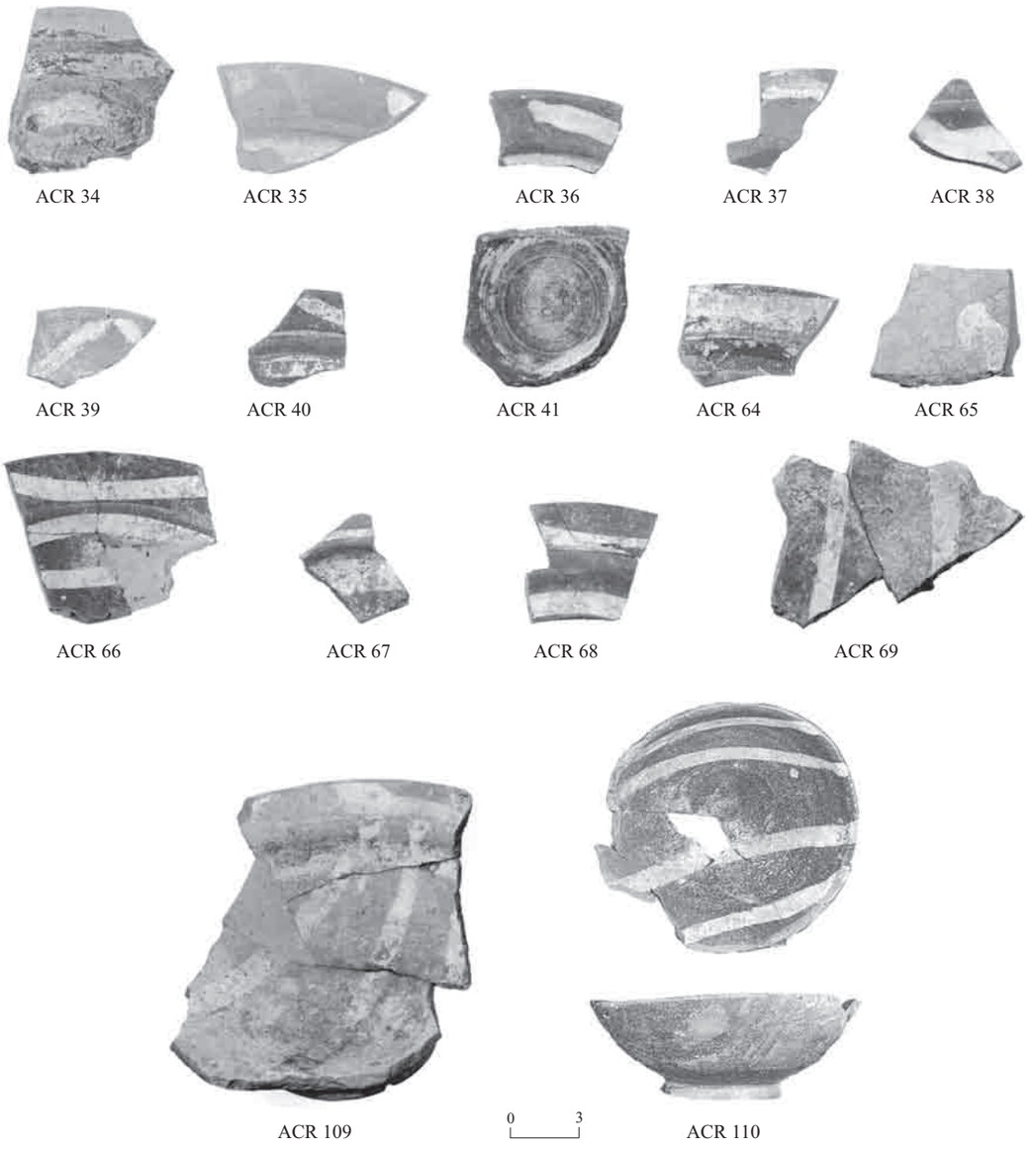


Fig. 6. Glazed bowls (slip-painted).

Similar pots have been found at many sites in Lebanon and Israel. Several examples illustrate their wide distribution: Beirut (El Masri 1998:108–109, Fig. 8:5–10), Tell ʻArqa (Thalmann 1978: Fig. 32; Hakimian and Salamé-Sarkis 1988: Fig. 111–6), Tripoli (Salamé-Sarkis 1980:214–216, Figs. 37, 38), Acre (Stern E.J. 1997:40–42, Fig. 5:22–36), Caesarea (Pringle 1985:176–177, Fig. 2:3–8; Arnon 1999:227, Fig. 12:d–f), and Yoqneʻam (Avissar 1996:135–136, Fig. XIII.93–96).

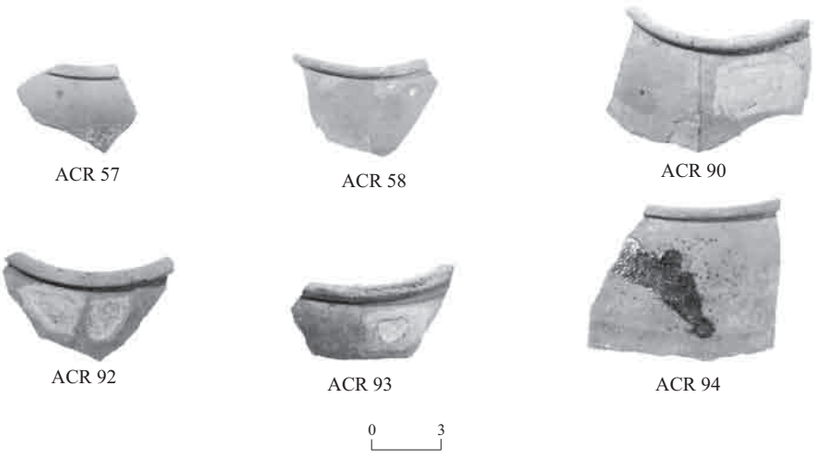


Fig. 7. Cooking pots (thin-walled).

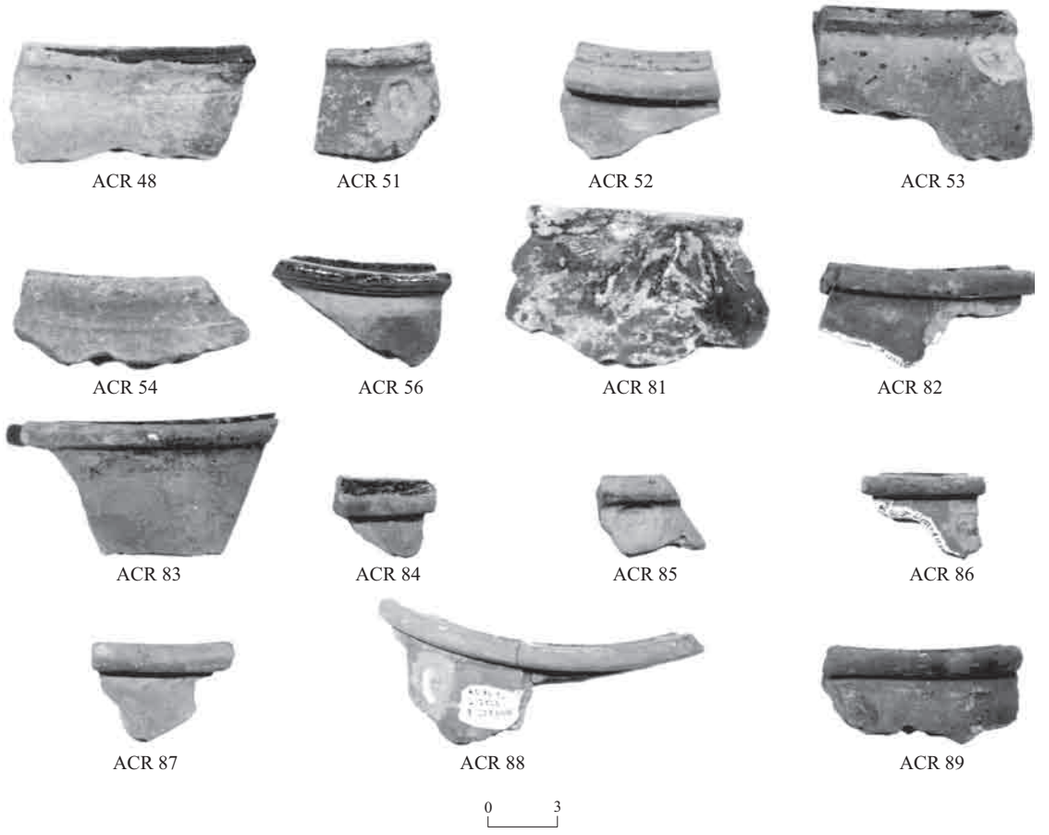


Fig. 8. Cooking pots (thick-walled).

IMPORTED WARES: ZEUXIPPUS FAMILY

Zeuxippus Ware is a well-distinguished group, named, defined, and divided into two main classes by Megaw (1968; 1989). This ware is not widely distributed in Israel and has been found mainly in large coastal sites held by the Franks. Large quantities of ceramics that share some features with and were possibly influenced by Zeuxippus Ware were found in the excavations at Acre.

We divided the Zeuxippus related ceramics into four groups according to shape, fabric color, glaze color, and decoration. Our Group I seems to be the genuine Zeuxippus Ware, or 'prototype' of the Zeuxippus Family, and is identical to Classes Ia and II as defined by Megaw (1968:69–72). Our Groups II and III are similar to Megaw's Classes Ib and Ic (1968:71). These groups seem to have been available in small quantities when Megaw defined Zeuxippus Ware, as ceramics published since then have greater variation. Our Groups II and III would belong to these variations. It is not clear whether they are derivatives or imitations of genuine Zeuxippus Ware, and it seems they came from sources other than those of the genuine type. At first, we defined Group IV as a member of the Zeuxippus Family. Now it seems very likely that it was manufactured in Venice, probably influenced by imported Zeuxippus Ware.

Group I (Figs. 9:1; 10)
This group has well-fired, hard, fine fabric. The fabric color ranges from reddish yellow,

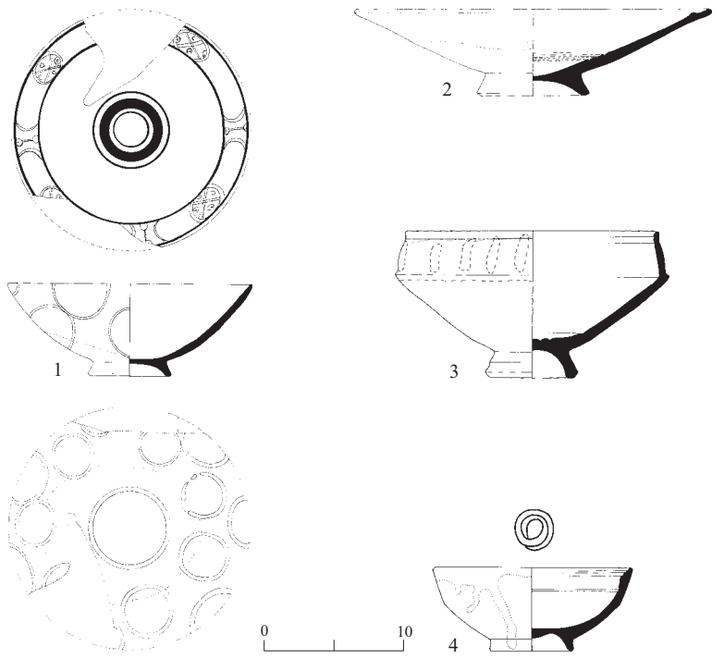


Fig. 9. Zeuxippus Family glazed bowls.

No.	Type	License/Permit No.	Locus	Basket
1	Group I*	G-102/92	13032	130393/1
2	Group II	see ZW14, Appendix 1		
3	Group III	see ZW38, Appendix 1		
4	Group IV	see ZW41, Appendix 1		

* Not examined in this study

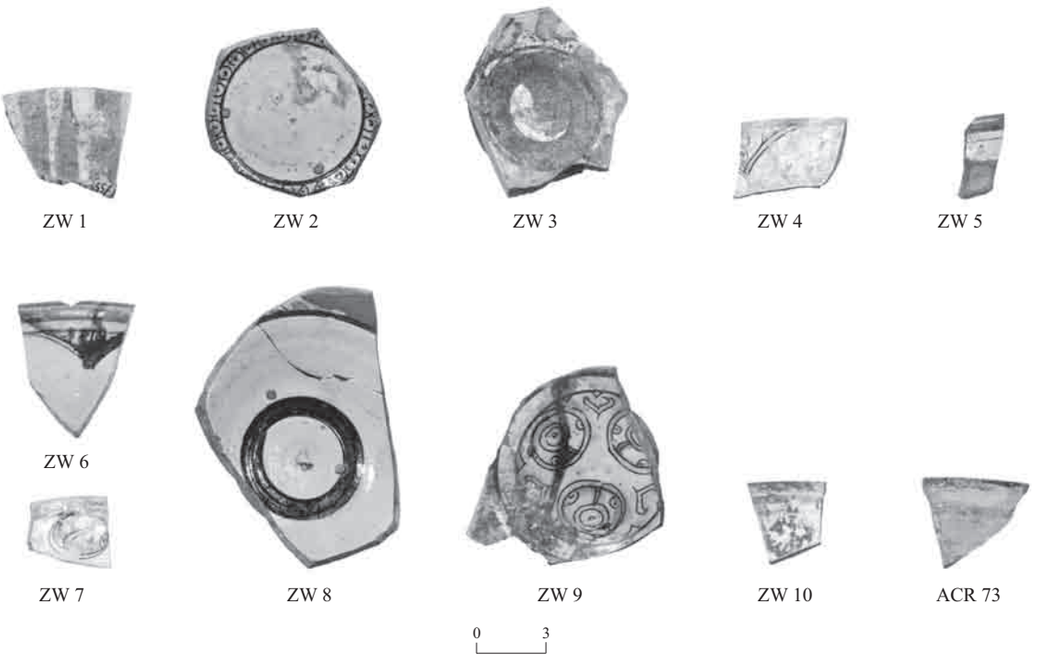


Fig. 10. Zeuxippus Family (Group I).

5YR 6/6, to yellowish red 5YR 5/6, sometimes varying from brown 7/5YR 5/4 to red 2.5YR 5/6. The typical vessel is a hemispherical bowl with extremely thin walls, simple and occasionally slightly everted or ledge rims, and hollow bases with a slightly everted foot that may be low or higher. The interior is covered with a thick layer of white slip and a fine shiny transparent lead glaze that is colorless, pale-yellow, or pale-green. Occasionally, the glaze extends to the exterior of the rim, halfway down the exterior, or almost to the base. Sgraffito decoration creates patterns on the interior, usually parallel lines near the rim and concentric circles in the base executed by thin incisions or wide gouging or a central medallion decorated with circular, triangular, or S-shaped motives, crosses, dots, or heart-shaped leaves. Splashes of brown glaze occasionally enhance the incised sgraffito design. Occasionally, the upper part of the exterior is decorated with loops or tongues of slip (Stern and Waksman 2003:171–172, Fig. 6: lower row, center; Avissar and Stern 2005:48–49, Fig. 19:1–4; Pl. XV). Bowls of this type were found in Israel at Acre (Stern E.J. 1997:52–54, Fig. 11; Edelstein and Avissar 1997:130, Fig. 1:3; Pringle 1997:144, Fig. 11:61, 62), St. Mary of Carmel (Pringle 1984:104, Fig. 8:57), Caesarea (Pringle 1985:190, Fig. 11:60), and Jerusalem (Tushingham 1985:147, Fig. 40:5). Outside Israel, this type was found, for example, at Al Mina (Lane 1937:43–45, Pl. XX, 1 unlettered), Corinth (MacKay 1967:258–261, Fig. 1:27, 28), Paphos (Megaw 1972:341, Fig. 38), Istanbul (Megaw 1968:71–77, Pl. 16:12–23), and Alexandria (François 1999:110, Fig. 25; Pls. 12:258, 262, 265, 267; 13:268).

Group II (Figs. 9:2; 11)

The fabric and glaze of Group II are of lower quality than Group I. The fabric color varies from red 2.5YR 5/6 and yellowish red 5YR 5/6 to light reddish brown 5YR 6/4. The glaze is light yellow, dark yellow-orange, or green in the interior, and extends just below the rim. Group II consists of bowls and dishes. The bowls are hemispherical with a slightly hollow

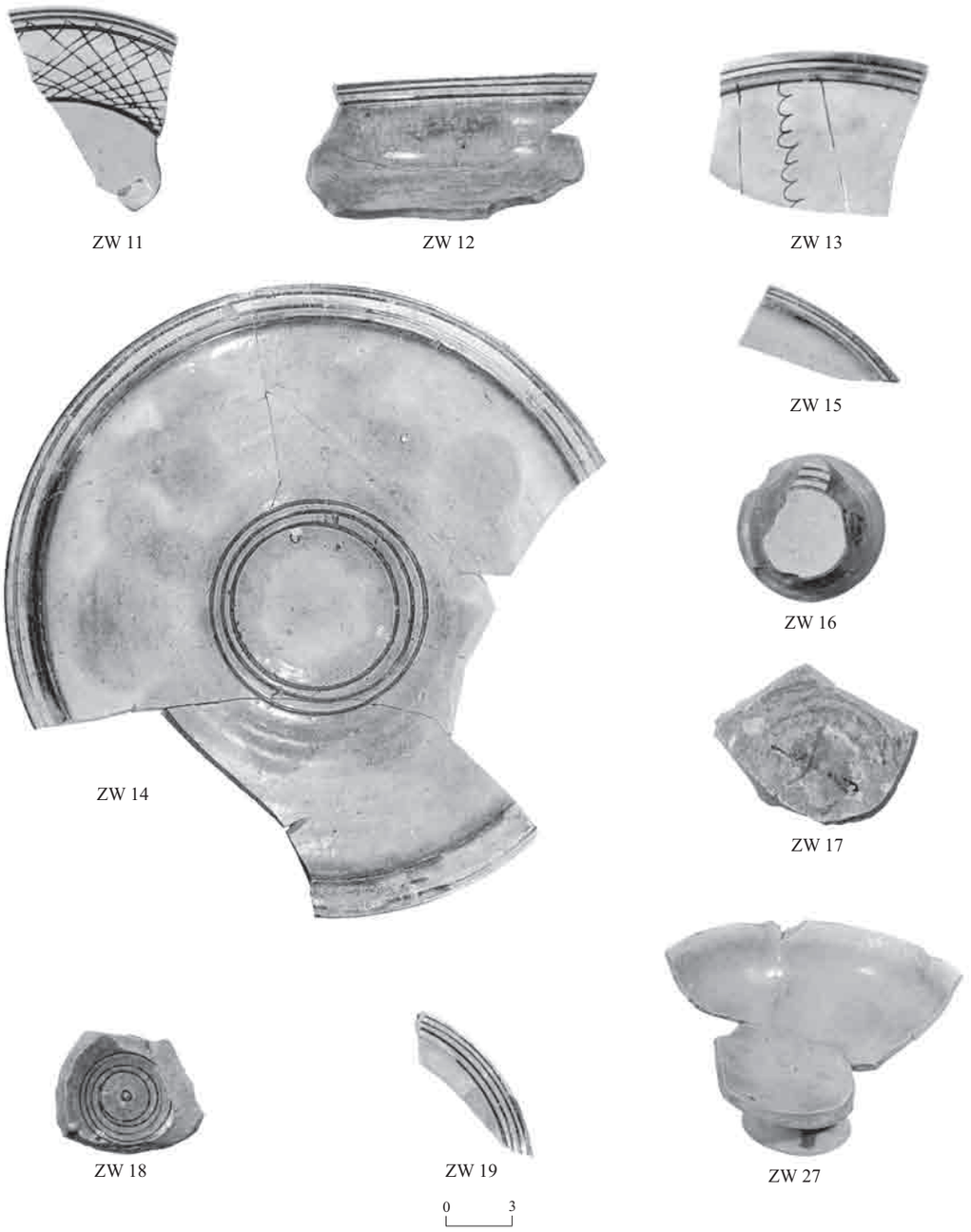


Fig. 11. Zeuxippus Family (Group II).

wide ledge or everted rims, or carinated at the shoulder with a simple rim. The dishes have slightly hollow everted rims. The bases are mainly low ring bases, but are sometimes a little higher. The designs are simpler than those of Group I and consist mainly of incised spirals or concentric circles on the interior of the base, sometimes with a letter or a sign incised in the

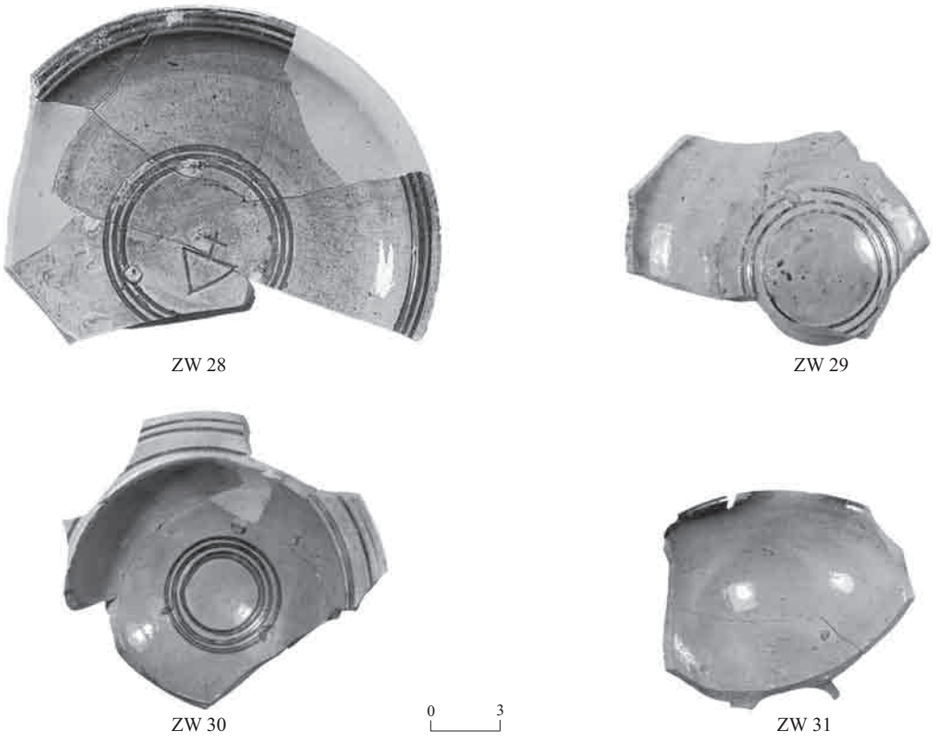


Fig. 11. (Cont.).

concentric circles, and horizontal incised lines on the rims (Stern and Waksman 2003:171–172, Fig. 6; Avissar and Stern 2005:51, Fig. 20, Pl. XVI). By shape, glaze, and decoration, this type is similar to the Cypriot thirteenth-century sgraffito Paphos ware (Papanikola-Bakirzi 1996:215–216; von Wartburg 1997:336) and may be related, i.e., influenced by the Cypriot type or vice versa. It seems this type corresponds to a type found in Sparta (Armstrong 1992) that is widespread in the eastern Mediterranean and Italy and can be precisely dated to the thirteenth century, mostly the second half. Bowls of this type from a site in Acre were dated to the end of the thirteenth century (Stern E.J. 1997:54–56, Fig. 12:87–94). Bowls that seem to be of Groups II and III were also found at Ḥorbat ʻUẓa (Stern and Tatcher, forthcoming), St. Mary of Carmel (Pringle 1984:104, Fig. 8:58), Corinth (MacKay 1967:252–254, Fig. 1; Pls. 62–63, Nos. 7–10), Sparta (Armstrong 1992; Sanders 1993:256–257), and Istanbul (Hayes 1992:47–48, Fig. 17:16, 17, 19, 22–24; Pls. 11: h–j, n, o; 12:a).

Group III (Figs. 9:3; 12)
Group III has similar shapes as Group II, but the fabric is lighter and there is a great amount of mica in the clay. The fabric varies from light reddish brown 5YR 6/4 and pink 5YR 7/4 to reddish yellow 5YR 6/6 and yellowish red 5YR 5/6. The glaze is usually dark yellow and applied in a similar manner as in Group II. In one example, the bowl is glazed in light yellow with strips of yellow-orange. The decorations on these bowls are similar to those of Group II.

Group IV (Figs. 9:4; 13)
Group IV shares the general characteristics of the previous groups. The fabric is reddish

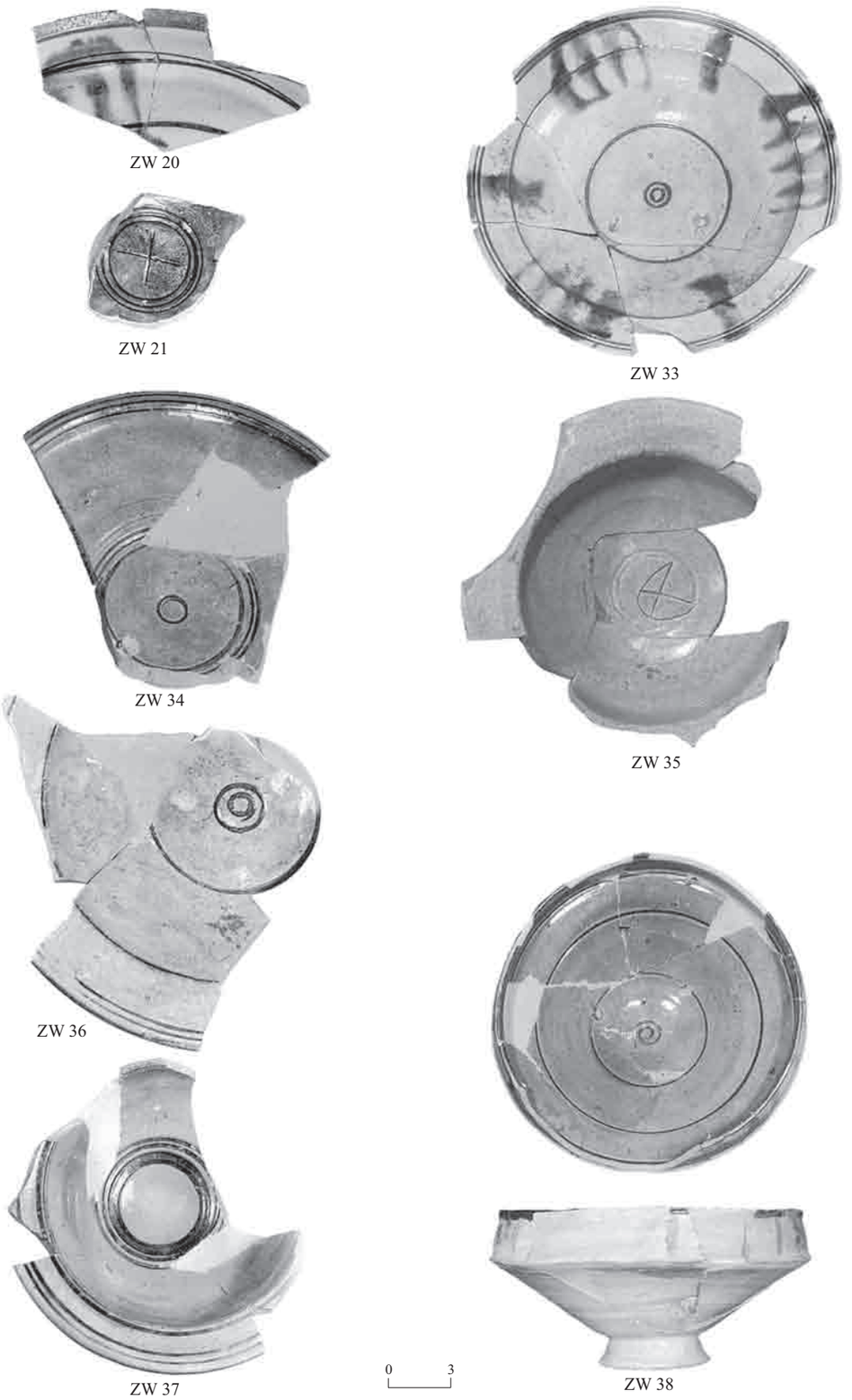


Fig. 12. Zeuxippus Family (Group III).

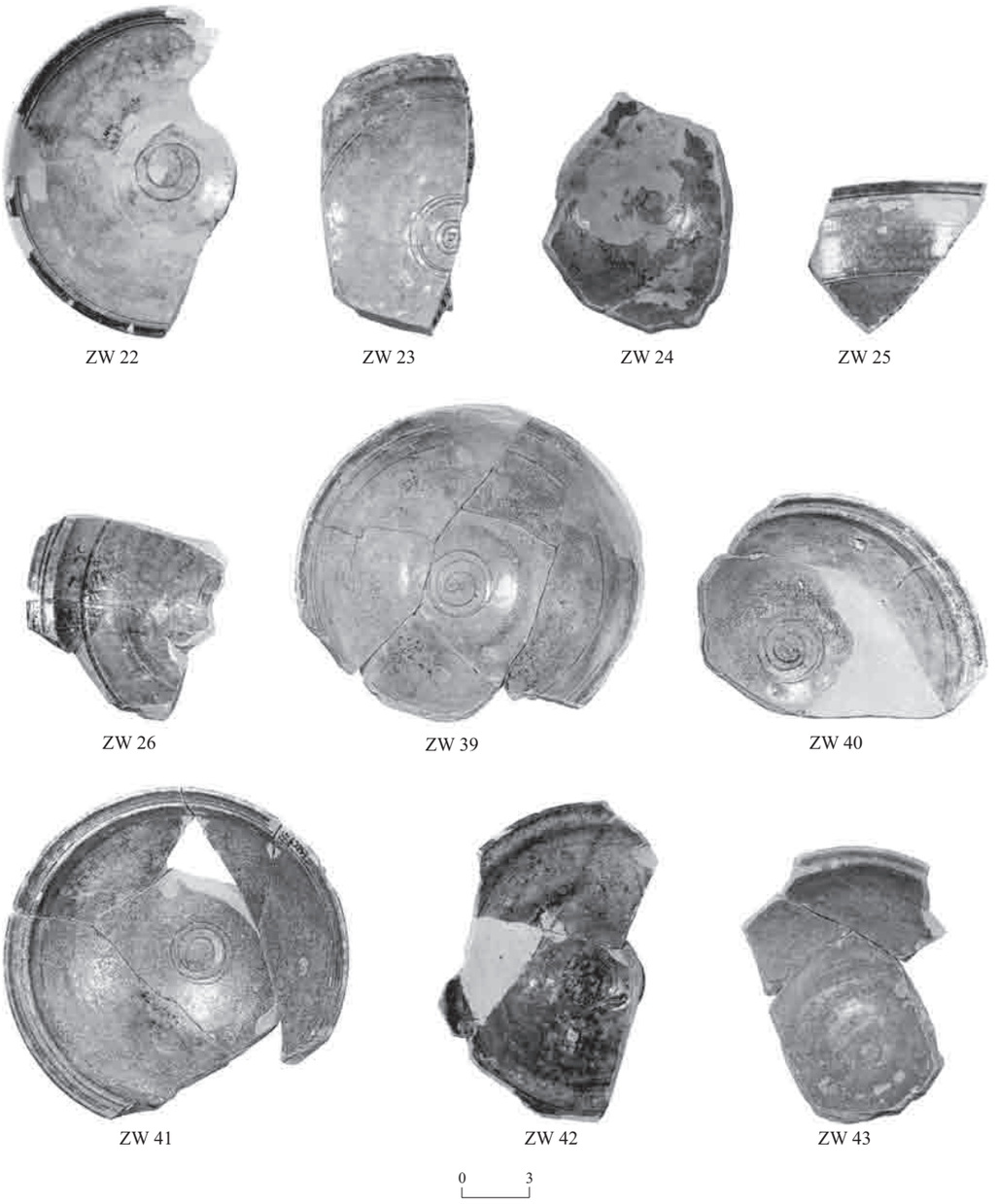


Fig. 13. Zeuxippus Family (Group IV).

yellow 5YR 6/8 to yellowish red 5YR 5/6 or strong brown 7/5 YR 5/6. The vessels are small hemispherical bowls with simple rims and low ring bases. Occasionally, the bowls are slightly carinated at the bottom part of the body. A white slip is usually present on the interior of the bowl and sometimes on the exterior. However, some examples do not have any slip. The glaze is yellowish brown or, less commonly, green and applied on the interior and entire exterior,

including the base. The decoration consists of horizontal incised lines on the rim and incised spirals or concentric circles on the base. Occasionally there is a rouletting decoration on the exterior of the bowl (Stern and Waksman 2003:172; Avissar and Stern 2005:70–71, Fig. 30:1–4; Pl. XXII:1–4). It seems these bowls from Acre belong to a type known from Italy by the name of Spirale-Cerchio (Saccardo 1993:212–214; Berti and Gelichi 1997:87–89); some may be defined as Roulette Ware (Gelichi 1984).

ANALYTICAL METHODS

Elemental analysis (also referred to as chemical analysis) determines the elemental composition of sherds, i.e., the concentration of elements constituting the ceramic material. Petrographic analysis determines the nature and details of minerals and rock fragments in thin sections of sherds under a polarizing microscope. Both methods may be used to classify sherds into groups of ceramics that are manufactured from similar raw materials. Under certain conditions, which mainly depend on the geological context, these groups may correspond to the products of the same workshop (Picon 1992). To investigate their origin, their characteristics are compared to those of reference groups of known origin or, in the case of petrography, to geological formations. The discovery of workshops, kiln furniture, or wasters, as in Acre, enables us to constitute such reference groups.

Elemental analysis was carried out by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the Geological Survey of Israel (Waksman et al. 1999). The major elements Na and K, which could not be determined by our ICP procedure, were analyzed by Instrumental Neutron Activation Analysis (INAA) at the Archaeometry Laboratory of the Hebrew University of Jerusalem. Eighteen elements, including major and minor elements (Mg, K, Al, Ca, Ti, Fe, Mn) and trace elements (V, Cr, Ni, Sr, Y, Ba, La, Ce, Eu, Yb, Th) were used to classify ceramics into groups sharing similar chemical compositions. Due to possible contamination during the sampling procedure (Co, Cu, Zn) or to unreliable values (Si), some elements were not taken into account (Waksman et al. 1999). The trace elements Nd, Sm, Tb, Lu and U were analyzed by ICP-MS at a late stage of the study and were therefore not used in the classifications, although their values are indicated.

Classification was carried out by hierarchical clustering analysis (HCA) applied to standardized data, using Euclidian distance and average linkage. The corresponding diagram, called a dendrogram, shows each sample as a vertical bar at the bottom of the figure (Figs. 14, 15). The two samples most alike in elemental composition are connected by a horizontal link; the lower the link, the more chemically similar the samples. The two samples are then fused into a □pseudo sample□ of average composition. The same process is repeated, with the linkage being formed at growing heights, until all the samples are connected. The resulting dendrogram shows clusters of samples of similar composition linked at a lower level, with all the clusters being ultimately linked together at the top of the diagram. This representation, however, is not sufficient in itself to define compositional groups. It does not take into account the significance of chemical differences between clusters, and further examination of the data is still needed. Groups constituted by this procedure are hereinafter referred to as compositional groups or groups after HCA classification.

Representative samples were chosen from each compositional group for petrographic analysis. Some samples for which HCA classification produced ambiguous results were also examined by this method. An independent classification was thus obtained, presented in detail in Waksman et al. 1999. The main results of the petrographic and elemental analyses are discussed here and interpreted in light of the archaeological data.

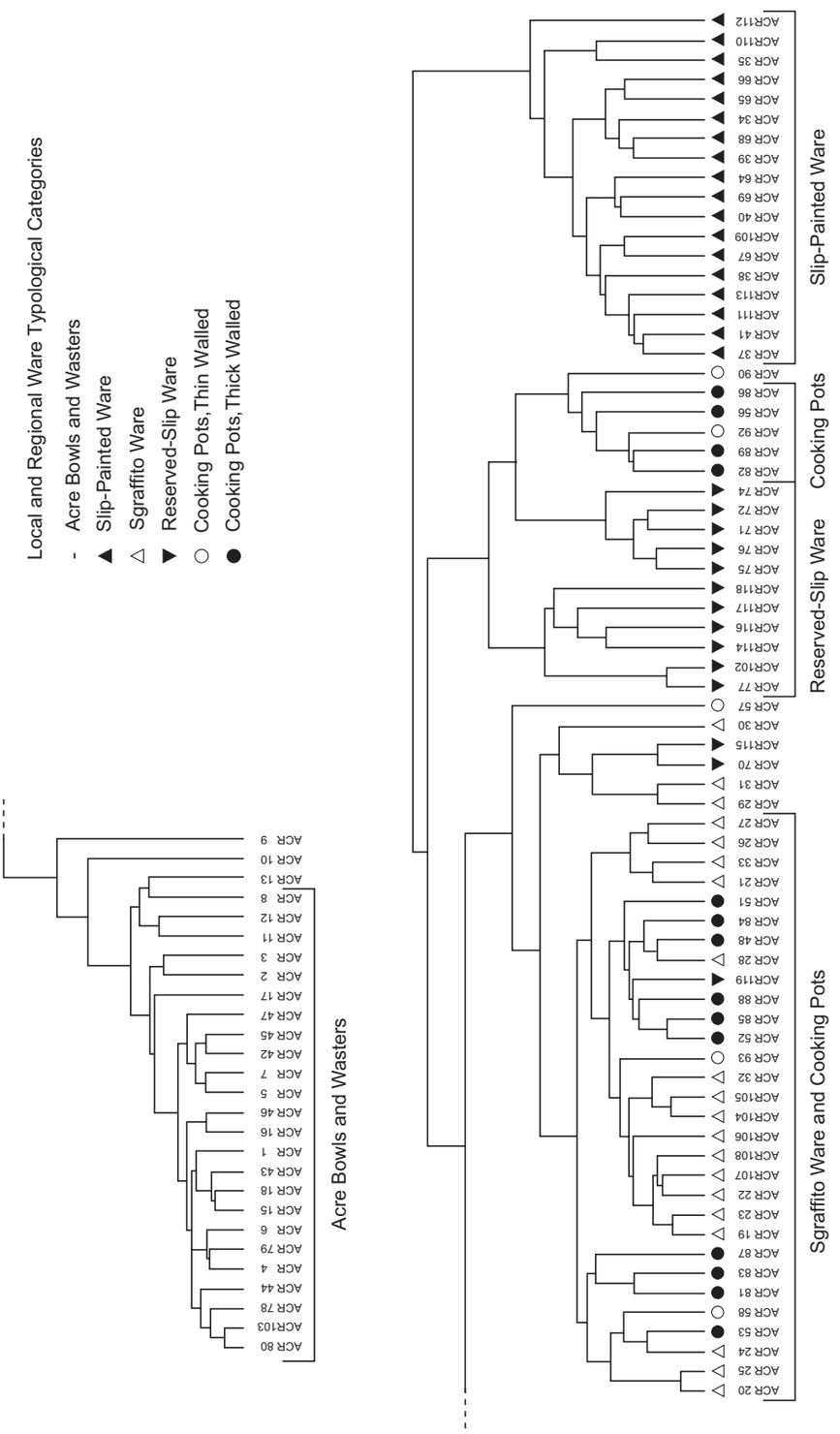


Fig. 14. Classification of local and regional wares. Dendrogram obtained by Hierarchical Clustering Analysis of 18 elements. Typological categories are represented by symbols. The main compositional groups are underlined.

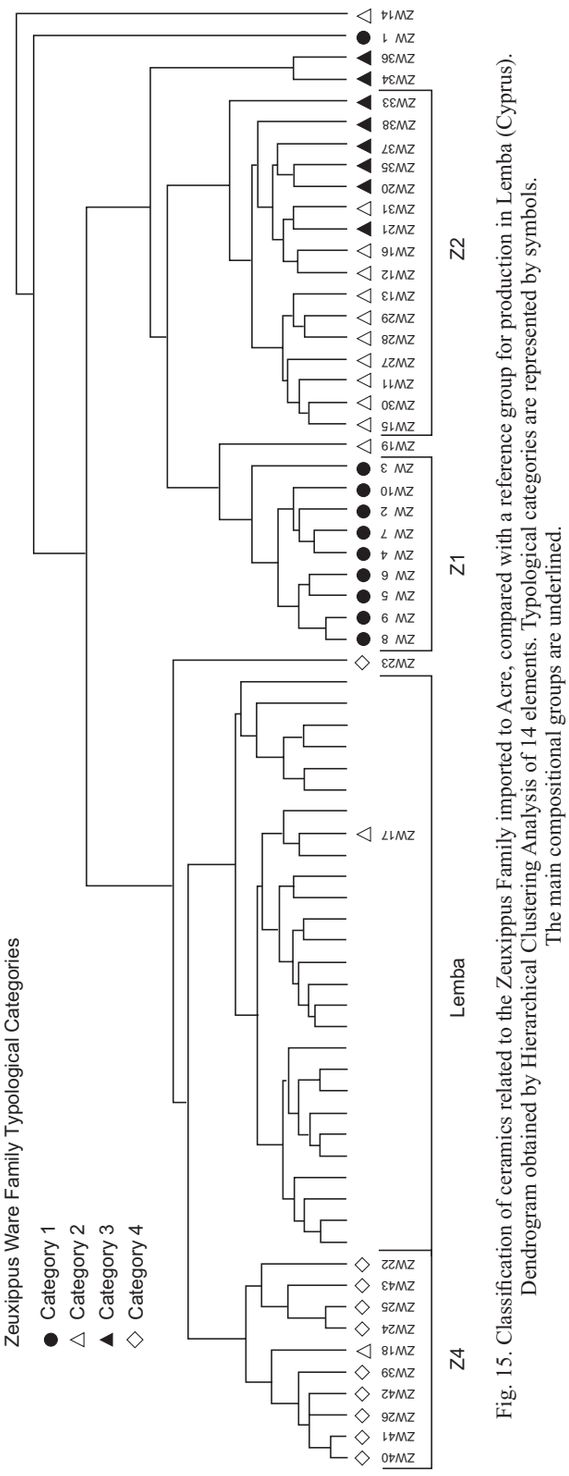


Fig. 15. Classification of ceramics related to the Zeuxippus Family imported to Acre, compared with a reference group for production in Lemba (Cyprus). Dendrogram obtained by Hierarchical Clustering Analysis of 14 elements. Typological categories are represented by symbols. The main compositional groups are underlined.

RESULTS

LOCAL AND REGIONAL WARES

Figure 14 shows the classification of about 100 sherds chosen as a representative sampling of the regional types of ware (Acre bowls; sgraffito, reserved-slip, and slip-painted glazed bowls; thick and thin-walled cooking pots). The main compositional groups are underlined in the figure. Mean compositions and standard deviations of each group are indicated in Table 1. Table 2 compares results of elemental and petrographic analyses with the typological classification. Two groups are well isolated in the dendrogram (Fig. 14). One corresponds to the slip-painted glazed bowls and the other to the Acre bowls together with most of the wasters. The latter group is also clearly differentiated by petrography. The sgraffito and reserved-slip glazed bowls and the cooking pots are either not so clearly separated from each other in the HCA classification or tend to constitute substructures. Most have similar petrographic features.

Table 1. Mean Elemental Compositions (m) and Standard Deviations (σ) of the Main Groups of Local and Regional Wares

Element	Acre Bowls and Wasters (N = 24)		Slip-Painted Ware (N = 18)		Sgraffito Ware and Cooking Pots (N = 30)		Cooking Pots (N = 5)		Reserved-Slip Ware (N = 11)	
	m	σ	m	σ	m	σ	m	σ	m	σ
Na_2O (%)	1.32	0.20	0.36	0.09	0.15	0.04	0.23	0.07	0.17	0.03
MgO (%)	3.24	0.34	1.48	0.20	0.68	0.14	0.93	0.22	0.84	0.23
Al_2O_3 (%)	13.46	1.00	15.03	0.97	11.45	1.13	13.63	1.33	17.96	1.15
K_2O (%)	1.71	0.27	1.50	0.28	0.55	0.14	0.84	0.22	1.38	0.32
CaO (%)	7.77	1.35	9.16	2.22	3.93	2.66	1.66	0.37	2.13	1.67
TiO_2 (%)	1.20	0.06	1.54	0.21	1.57	0.12	1.50	0.13	2.15	0.19
Fe_2O_3 (%)	7.48	0.45	12.81	1.39	8.25	0.75	10.30	0.91	10.48	2.09
MnO (%)	0.132	0.010	0.091	0.018	0.059	0.021	0.139	0.020	0.072	0.014
V (ppm)	121	10	168	15	105	14	117	15	113	24
Cr (ppm)	142	13	234	14	146	10	181	13	176	13
Ni (ppm)	69	7	141	10	61	8	104	7	83	18
Sr (ppm)	307	41	284	59	95	40	83	9	129	23
Y (ppm)	40.6	2.2	43.5	7.4	33.8	5.4	66.3	6.1	52.1	11.7
Ba (ppm)	386	71	629	193	149	29	233	25	149	36
La (ppm)	42.0	2.6	38.6	2.9	31.4	5.0	55.8	5.1	59.5	5.7
Ce (ppm)	86	6	66	9	69	10	84	7	110	9
Nd (ppm)	39	2	38	5	32	4	55	4	55	9
Sm (ppm)	8.0	0.5	8.3	1.4	6.6	1.0	11.8	0.9	11.4	2.3
Eu (ppm)	1.85	0.12	2.16	0.37	1.53	0.24	2.86	0.17	2.90	0.61
Tb (ppm)	1.1	0.1	1.2	0.2	1.0	0.1	1.8	0.1	1.6	0.3
Yb (ppm)	3.6	0.2	3.5	0.3	3.2	0.3	4.7	0.4	4.3	0.7
Lu (ppm)	0.53	0.04	0.51	0.04	0.52	0.05	0.76	0.06	0.69	0.10
Th (ppm)	9.3	0.6	7.0	0.7	9.1	1.1	9.5	1.2	10.7	1.7
U (ppm)	2.4	0.2	3.1	0.2	2.5	0.3	3.5	0.3	2.5	0.4

N = number of samples

Table 2. Comparison of Typological, Elemental, and Petrographic Classifications

Sample	Typological Group	Elemental Group	Petrographic Group*
Regional Categories of Ware			
ACR44	Acre bowl	Acre bowl	1
ACR46	Acre bowl	Acre bowl	1
ACR47	Acre bowl	Acre bowl	1
ACR80	Acre bowl	Acre bowl	1
ACR20	Sgraffito bowl	Sgraffito/cooking pot	2
ACR22	Sgraffito bowl	Sgraffito/cooking pot	2
ACR26	Sgraffito bowl	Sgraffito/cooking pot	2
ACR72	Reserved-slip bowl	Reserved-slip	2
ACR76	Reserved-slip bowl	Reserved-slip	3
ACR77	Reserved-slip bowl	Reserved-slip	2
ACR37	Slip-painted bowl	Slip-painted	3
ACR64	Slip-painted bowl	Slip-painted	3
ACR68	Slip-painted bowl	Slip-painted	3
ACR51	Thick-walled cooking pot	Sgraffito/cooking pot	2
ACR52	Thick-walled cooking pot	Sgraffito/cooking pot	2
ACR56	Thick-walled cooking pot	Cooking pot	2
ACR82	Thick-walled cooking pot	Cooking pot	3
ACR83	Thick-walled cooking pot	Sgraffito/cooking pot	2
ACR85	Thick-walled cooking pot	Sgraffito/cooking pot	2
ACR86	Thick-walled cooking pot	Cooking pot	2
Imported Ceramics related to Zeuxippus Ware			
ZW1	Group I	Unclassified	3
ZW3	Group I	Z1	4
ZW6	Group I	Z1	4
ZW10	Group I	Z1	4
ZW11	Group II	Z2	4
ZW13	Group II	Z2	4
ZW15	Group II	Z2	4
ZW18	Group II	Z4	4
ZW20	Group III	Z2	4
ZW22	Group IV	Z4	4
ZW23	Group IV	Unclassified	4
ZW25	Group IV	Z4	4

* 1: coastal; 2: mature siliclastics; 3: red glassy fragments; 4: micaceous-metamorphics

Ceramics Manufactured in Acre

A first compositional group includes all the Acre bowls and five Acre-bowl wasters. The fact that the wasters belong to this group designates it as a reference group for local production. The corresponding samples have higher alkali and alkaline-earth contents than most of the other samples, except for the group of slip-painted glazed bowls. Petrographic analysis of the Acre bowls identified an assemblage of well-sorted quartz, decomposed carbonates, accessory minerals, feldspars, epidote, hornblende, and

chert, indicative of the coastal Pleistocene formations of Israel that occur around Acre.

Two overfired samples that were first identified as wasters were excluded from the group. One is a global outlier (not represented in Fig. 14) with characteristics that are alien to the local geology (high Mg, Cr, and Ni contents typical of ultrabasic contexts), which refute its status as a waster.

Regional Production

The glazed bowls and cooking pots had quite different characteristics from the Acre bowls' compositional group. Petrographic analysis identified a mineralogical basis common to both the bowls and the cooking pots: mainly medium to poorly-sorted quartz, few if any large carbonate grains, few stable heavy minerals epidote, zircon, and tourmaline, occasional shale fragments, and rare chert grains. These features correspond to a mature siliclastic formation that would include sandstone, shale, and perhaps siltstone. Such a geological context is not widespread in Israel and is probably related to the Lower Cretaceous formations that crop out in large occurrences on the slopes of Mount Hermon in northern Israel, across Lebanon, and in Transjordan. It does not occur in the close vicinity of Acre and these wares are therefore considered imported to Acre.

The wares share some common elemental features, such as high Fe and Ti, but they are classified by HCA into one well-defined group that closely corresponds to the slip-painted ware, one large heterogeneous structure that includes most of the sgraffito ware and cooking pots, a subgroup of reserved-slip wares, a subgroup of cooking pots, and some unclassified sherds. Thin- and thick-walled cooking pots are present in both the heterogeneous group and the subgroup of cooking pots.

The best individualized group is the one which (strictly) corresponds to the slip-painted wares. It is characterized by higher contents of Fe (almost 13% Fe_2O_3) and transition elements of the Fe series (V, Cr, Ni) than the other regional types of wares. Ceramics in this group are also more calcareous and have comparatively higher alkali and alkaline-earth contents. They were distinguished by petrography as the only ones with iron oolithes and probably (very degraded) basalt fragments. They contain up to 5% red glassy fragments that are sometimes finely banded, isotropic, or have a chalcedony fibrous radiating texture. The latter are less specific, since they are also present in two other samples (one reserved-slip bowl and one cooking pot). Because of these features, the slip-painted bowls are seen as a distinct production, even though they share some petrographic and elemental characteristics with the other regional wares.

The situation is more ambiguous for the sgraffito ware, reserved-slip ware, and cooking pots. They have the same petrographic features (except for the above two samples) and share distinctively low alkali and alkaline-earth contents. However, substructures partly related to rare earth element (REE) concentrations may be distinguished. The large heterogeneous structure that includes most of the sgraffito ware, part of the cooking pots, and one sample of reserved-slip ware has high coefficients of variation and an especially variable (though generally low) Ca content. The subgroup of cooking pots differs primarily by its higher Y and REE contents. The reserved-slip subgroup is characterized by higher Al and Ti contents. Variable REE contents are responsible for splitting this group into two subgroups in the dendrogram. However, since the REE concentration values vary rather continuously, we decided not to divide the group into two, as we had in an earlier step of the study (Waksman et al. 1999).

Discussion

The presence of Acre-bowl wasters in Acre, the finding of Acre bowls almost exclusively in the vicinity of Acre, the distinct features of this compositional group and the inclusion of most of the wasters in it, and the coastal mineralogical assemblage present a coherent picture of this group, designating it as a reference for production in Acre.

The other regional types (glazed bowls and cooking pots) are related to geological formations that do not occur near Acre and are, therefore, considered imported. Since our local reference group includes only Acre bowls and Acre-bowl wasters, this is the only item within our sampling that was proven *stricto sensu* to have been produced locally. This conclusion does not quite agree with an earlier petrographic study of a sampling that included Acre bowls and cooking wares (Goren 1997). That study showed that most of the examined cooking wares and some of the Acre bowls were likely to have been produced locally, while the remainder of the Acre bowls was related to lower Cretaceous formations. These were interpreted as additional stock, imported in cases of heavy pilgrimage (Stern E.J. 1997:37). The reason for the apparent contradiction between Goren's study and ours is not clear. Doubt is cast on our conclusion regarding the cooking wares by texts that mention a street of cooking pot makers in thirteenth century Acre (Pringle 1986). However, as Pringle notes, "whether these craftsmen were working in clay or metal is less certain" (Pringle 1986:470). Since our study, other types of vessels found in Acre (jars, jugs, plates, amphoras), the clay of which is visually similar to that of the Acre bowls, were investigated by petrography (Shapiro, forthcoming). These vessels were shown to be local as well, extending the repertoire of forms attributable to Acre.

Even if other wares we did not sample were manufactured in Acre, it is significant that our study shows that several categories of the most common wares of the medieval Levant were not produced there. This finding provides information, but also raises questions regarding the production and trade of such wares. If we consider our sampling to be representative of the corresponding typological categories, different cases may be possible, as discussed below.

The homogeneity of the composition of the slip-painted ware samples and the clear distinction between these and the other groups of wares, suggest a single site of manufacture that specialized in slip-painted ware or used a distinct raw material to manufacture it. M. Picon (pers. comm.) suggested that such a workshop may have manufactured several types of wares but only slip-painted bowls reached Acre. If so, this would indicate that Acre was not part of the workshop's 'local market' in which its range of products would have been represented. It may imply that the workshop was distant and only some of its production was widely distributed.

For the other categories of regional wares, the varied composition may be due to production from several workshops and/or the use of a variety of raw materials with different elemental characteristics within a single workshop. If such a variety of raw materials was used within a single workshop, there was significant variability in REE among the available clays. These questions are at least partly answered by recent studies of ceramics from the excavations of the Beirut city center. Medieval pottery kilns were found there together with ceramics similar to our regional wares (Arnaud, Llopis and Bonifay 1996; El-Masri 1998; François et al. 2003). Elemental analyses of Beirut's local wares were carried out and reference groups were constituted (Waksman 2002; François et al. 2003). Comparisons with our analyses of Acre's sgraffito and reserved-slip glazed bowls and cooking pots showed that it is very likely that they were imported from Beirut (Waksman 2002).

The variability of clays used in the Beirut workshops is well demonstrated in these studies, as is further reflected in our groups from Acre. Also reflected here is the fact that some table and cooking wares were manufactured in Beirut with the same clays. There is no evidence of specialization of production, at least as far as raw materials are concerned. Cooking pots, however, are always made of low-calcareous clays which are more suitable for wares that must withstand thermal stress (Picon 1995).

It is also noticeable that the typological and chronological distinctions between the thin- and thick-walled cooking pots were not observed in

our results, as both categories are represented in both the sgraffito/cooking pot group and the cooking pot subgroup. This result, based on an insufficient number of samples, has been confirmed with a more extensive sampling from Beirut (Waksman, forthcoming). It means that the typological evolution of shape over time was not accompanied by a change in clay. It also suggests that the organization of ceramic production did not undergo significant changes between the Fatimid and Frankish rules.

The ferrugineous clays derived from lower Cretaceous formations exploited in Beirut were used to manufacture pottery from the Neolithic period (see Porat and Greenberg 1996, and Goren 1995 for detailed petrographic features and locations of major and minor occurrences of lower Cretaceous formations in Israel). A rather large range of composition was observed among these ceramics. Some results have little in common with our data: a Chalcolithic sherd has a 7.5% Fe_2O_3 content, comparable to the lowest values in our sampling, but with much lower Ti and higher K and Mg contents than ours (Edwards and Segnit 1984; Goren 1995); the Fe content of Bronze Age metallic ware found in Abydos is even lower (Porat 1989). On the other hand, metallic wares uncovered in Tel Dan and elsewhere have Fe (10% Fe_2O_3 and above) and Ti (average 1.9% TiO_2) contents comparable to our results (Porat and Greenberg 1996), while Roman ceramics from the Kefar Ḥananya workshop and clays from the nearby Ḥananya valley have compositions that resemble the less calcareous, more REE-rich compositions of our groups (Adan-Bayewitz and Perlman 1985; Wieder, Adan-Bayewitz and Asaro 1994). These comparisons suggest that clays, which developed on lower Cretaceous sediments in different locations, may be distinguished in spite of important variations observed in a single location, as seen in the case of productions from Beirut found in Acre.

ZEUXIPPUS WARE

Forty-two samples classified in four typological categories of Zeuxippus-related ware were examined. They are clustered by HCA into three well-differentiated compositional groups, with a few samples unassigned (Groups Z1, Z2, Z4; Fig. 15). They are easily distinguished chemically from the local and regional wares, from the latter by their higher alkali contents. Petrographic analysis confirms their imported status, as the metamorphic elements in their pastes rule out a regional origin. Except for sample ZW1, all the samples examined by petrography have similar features (Table 3), which may illustrate the difficulty of discerning by this method different productions of fine wares. The sherds have a finely micaceous matrix with varying amounts of silty quartz. They are lightly tempered with well-sorted subrounded quartz, micas, metamorphic rock fragments, decomposed carbonate grains, feldspar, oxyhornblende, mudballs, and micro-quartz, indicating a metamorphic terrain with nearby plutonic rocks such as granite. The fine matrix, quartz, and mica indicate that the clays probably derived from soils or river deposits.

Group I

Elemental analysis confirms that the samples in typological Group I, except for ZW1, correspond to a well-defined and homogeneous compositional group (Z1) with noticeably low coefficients of variations (well below 10% except for Ca and Sr). The sherds in Group I (including ZW1) have a distinctive slip of pure clay, whereas the slips of the other samples are clays with various amounts of inclusions, particularly quartz. Information regarding slips of the medieval period is still scarce although recent research on slips shows its discriminating potential, especially in the case of Zeuxippus Ware (Berti, Capelli and Mannoni 2001; Capelli and Cabella 2007).

Outlying sample ZW1 is characterized by high Al and low alkali, alkaline-earth, and manganese contents, suggesting a strong kaolinitic component. According to petrographic analysis, it belongs to petrographic Group 3 together with the slip-painted ware. The typological characters of ZW1 (mainly the

Table 3. Mean Compositions (m) and Standard Deviations (σ) of Chemical Groups of Ceramics of the Zeuxippus Ware Family

Element	Group Z1 (N = 9)		Group Z2 (N = 17)		Group Z4 (N = 10)		ZW1
	m	σ	m	σ	m	σ	
Na_2O (%)	1.04	0.07	0.56	0.12	1.63	0.20	0.37
MgO (%)	3.51	0.25	4.17	0.39	2.22	0.29	0.77
Al_2O_3 (%)	14.89	0.62	19.13	0.95	18.92	1.45	22.86
K_2O (%)	2.48	0.17	3.30	0.26	4.29	0.34	1.19
CaO (%)	8.33	1.15	11.48	1.13	1.58	0.93	1.54
TiO_2 (%)	0.83	0.02	0.71	0.03	0.77	0.02	0.73
Fe_2O_3 (%)	7.09	0.28	8.01	0.46	5.80	0.57	5.28
MnO (%)	0.156	0.012	0.131	0.021	0.054	0.010	0.024
V (ppm)	129	12	130	11	102	11	85
Cr (ppm)	245	13	303	33	106	10	71
Ni (ppm)	152	8	224	33	49	5	35
Sr (ppm)	297	50	295	39	110	17	69
Y (ppm)	29.4	0.8	37.6	1.8	39.8	2.3	20.8
Ba (ppm)	439	31	436	32	692	93	153
La (ppm)	32.4	1.1	44.1	2.7	50.8	3.8	28.9
Ce (ppm)	61	4	76	6	95	6	52
Nd (ppm)	29	1	36	3	43	3	25
Sm (ppm)	5.7	0.3	7.2	0.5	8.7	0.5	4.5
Eu (ppm)	1.30	0.07	1.54	0.12	1.67	0.13	1.16
Tb (ppm)	0.8	0.1	1.0	0.1	1.2	0.1	0.6
Yb (ppm)	2.8	0.1	3.3	0.2	3.6	0.2	1.9
Lu (ppm)	0.39	0.03	0.47	0.03	0.53	0.03	0.27
Th (ppm)	10.6	0.3	14.4	1.6	16.1	3.4	11.0
U (ppm)	2.8	0.1	3.9	0.7	3.1	0.2	2.7

N = number of samples

shape of the vessel) do not belong exclusively to Group I, and the sherd was placed in this group primarily due to the tongues of slip on the exterior. The appearance of its paste, pinkish in color, is, however, quite different from that of the Zeuxippus ware. Therefore, it is not surprising that the elemental and petrographic analyses showed it to be an outlier.

Groups II and III

Most of the samples of typological Groups II and III belong to the same compositional group (Z2) of rather calcareous ceramics (c. 12% CaO) with the highest Fe, Mg, Cr, and Ni concentrations of all the Zeuxippus-related samples. Group III samples slightly differ in that they seem to have the lowest Al, Ti, Fe and transition element concentrations within Group Z2, a trend that may become clearer with extended sampling. Sample ZW14 is characterized by a much higher Ba content, but as this element may be incorporated into a sherd during burial (Picon 1987) or as an accidental grain of Barite, the sample was still included in Group Z2 (but not in the calculation of average Ba concentration and standard deviation).

Group IV

Except for sample ZW23, Group IV corresponds to a distinct compositional group (Z4) with low Ca (1–2% CaO), Sr, Cr, and Ni and high Ba contents. ZW18, originally included in Group II, falls into this compositional group.

Discussion

From its finer fabric, Group Z1 may be seen as a "prototype" for the other Zeuxippus Family wares. This hypothesis is supported by the compositional similarity of the Z1 sherds with the large group of "Zeuxippus Ware *stricto sensu*" defined by Waksman and François (2004–2005) that included samples from Italy, France, Greece, Turkey, Ukraine, Cyprus, Lebanon, and Egypt. For the latter study, chemical analysis was carried out by X-Ray Fluorescence in the Laboratoire de Céramologie in Lyon (France). The classification of data from the different laboratories (Jerusalem and Lyon) was performed after an inter-calibration found to be workable for fourteen elements (Waksman 2002; 2006).

There are few clues to the location of the production site of Zeuxippus ware (Megaw, Armstrong and Hatcher 2003; Waksman and François 2004–2005). Due to the large amounts of ceramics of this type discovered in urban excavations in Istanbul, Zeuxippus ware is thought to be a Constantinopolitan production, although there are no field discoveries so far to confirm this hypothesis. Megaw and Jones (1983:263) suggested an Aegean origin on the basis of the elemental similarity of two sherds of Zeuxippus ware from Paphos and one sherd of "Aegean Ware" (Megaw 1975), which is refuted by recent analyses (Waksman and von Wartburg 2006). Boas proposed a Cypriot origin for one of his groups of Zeuxippus ware on the basis of its elemental similarity with typical thirteenth-century Cypriot slip-painted and sgraffito wares (Boas 1991:200; 1994:118). Thirteenth-century productions from Lemba near Paphos, commonly considered typological references for Cypriot production of this period, were analyzed in the Laboratoire de Céramologie in Lyon. Figure 15 presents a classification including our Group Z1 and a reference group for Lemba and shows the two groups to be very different chemically.

Likewise, the elemental composition of Z2 differs from the composition of samples from Lemba. With the exception of ZW17, the composition of which matches the Lemba reference, none of the ceramics that we sampled appear to be imported from this part of Cyprus. It is not known whether another Cypriot workshop could have supplied the ceramics associated with Groups II and III, as no other workshop with comparable production has yet been identified. Sample ZW17 may be a Cypriot product that was mistakenly identified as Zeuxippus ware, demonstrating the similarity of Z3 to the Cypriot production (for a drawing of this vessel, see Stern E.J. 1997:55, Fig. 12:94). It is possible that the base of ZW17, which is missing, should be reconstructed as a high ring base characteristic of the Lemba production.

Our ability to attribute sherds to an origin is very limited given the present knowledge of medieval production sites. A handful of researchers, starting with Megaw and Jones (1983), aimed at defining analytical reference groups for well-identified production sites in the Eastern Mediterranean area, such as Corinth, Thessaloniki and Lemba. Western productions influenced by Byzantine imports, particularly Venetian, have attracted interest (Calogero and Lazzarini 1983; Lazzarini and Calogero 1989). At least four workshops manufactured Zeuxippus-related wares (Waksman and François 2004–2005): Pergamon (Waksman and Spieser 1997: Series B), Lemba (Megaw and Jones 1983:263) or another workshop in the region of Paphos, Nicea and Venice (Berti and Gelichi 1997:87–89). As we have just seen, the region of Paphos is not a likely provenance for our Groups Z1 and Z2. Neither is Pergamon, according to the comparison with compositions of Zeuxippus ware derivatives and other ceramics manufactured there (Waksman 1995: Group byzl; Waksman and Spieser 1997: Main Local Group).

The most relevant comparison is between Group Z4 and Venetian productions. Our data roughly agree with those published by Calogero and Lazzarini (1983:68; Lazzarini and Calogero 1989:582), although manganese is much higher and calcium more variable in the Venetian data. The difference in calcium is of little significance since this element is usually relatively variable and globally low in both cases. There is better agreement between the composition of Z4 and a more recent and extensive study of Venetian production by Mignucci (2002). Both typological and elemental characteristics point to a Venetian origin for these ceramics.

CONCLUSION

This study enabled the establishment of a new analytical reference group that corresponds to ceramic production in Acre during the Crusader period, when the port was of particular importance in the eastern Mediterranean area. Within our sampling, only the simple unglazed 'Acre bowls', which seem not to have diffused beyond the immediate Acre vicinity, were shown to be locally manufactured. However, since our study, other types of vessels found in Acre (jars, jugs, plates, amphoras) were demonstrated to be local as well (Shapiro, forthcoming).

A main finding is that the regional categories of ceramics□ sgraffito, slip-painted, reserved-slip wares and glazed cooking pots□ which have a larger diffusion and are typical of Levantine Crusader sites, are shown to have been imported into Acre. The slip-painted ware clearly differs from the other categories by its elemental and petrographic features, pointing to specific production or export of this ware to Acre, perhaps from a distant site. Cooking pots, sgraffito, and reserved-slip wares are related by petrography to lower Cretaceous formations that do not crop out in the near vicinity of Acre. Beirut, which sits on such geological formations and where medieval kilns were recently excavated, appears to be a most probable origin for these wares.

The present study also resulted in information about some categories of ceramics imported to Acre that are related to the Byzantine-type Zeuxippus ware. Three compositional groups were defined and characterized, one corresponding to a potential prototype for the other two. Only one group may be attributed to its origin (Venice), while other hypotheses of provenance were not confirmed by elemental analysis. The identification of the provenance of these imported wares relies on the availability of appropriate analytical data corresponding to reference groups of known origin. The development of databases specific to late Byzantine and Crusader material, to which this study contributes, is directed toward constituting a basis for such research.

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Appendix 1: Index of Sampled Sherds

Sample No.	Typological Category	License/Permit No.*	Locus No.	Basket No.	Figure	In E.J. Stern 1997	Note**
ACR1	Acre bowl	A-1763	115	1124/2	3	Fig. 4:3	1
ACR2	Acre bowl	A-1763	111	1076/1	3	Fig. 4:5	1
ACR3	Acre bowl	A-1763	128	1229/10	3	Fig. 4:2	1
ACR4	Acre bowl	A-1763	128	1229/6	3	Fig. 4:4	1
ACR5	Acre bowl	A-1763	128	1229/7	3	Fig. 4:8	1
ACR6	Acre bowl	A-1763	102	1024/1	3	Fig. 4:1	
ACR7	Acre bowl	A-1763	102	1054/1	3	Fig. 4:6	1
ACR8	Acre bowl waster	G-102/92	12035	121144/A	1		
ACR9	Acre bowl waster	G-102/92	13007	130038/A	1		
ACR10	Acre bowl waster	G-102/92	12011	120162/B1	1		
ACR11	Acre bowl waster	G-102/92	13013	130154/A	1		
ACR12	Acre bowl waster	G-102/92	13031	130383/A	1		
ACR13	Acre bowl waster	G-102/92	12018	120432/A	1		2
ACR14	Acre bowl waster	G-102/92	11014	110198/C	-		2, 4
ACR15	Acre bowl	G-102/92	12038	121184/18	3		2
ACR16	Acre bowl	G-102/92	-	121179/9	3		2
ACR17	Acre bowl	G-102/92	12036	121159/6	3		2
ACR18	Acre bowl	G-102/92	12038	121184/6	3		2
ACR19	Sgraffito bowl	A-2244	142	1242/2	4		
ACR20	Sgraffito bowl	A-2244	143	1242/1	4		3
ACR21	Sgraffito bowl	A-2244	675	2333/16	4		
ACR22	Sgraffito bowl	A-2244	142	1248/13	4		3
ACR23	Sgraffito bowl	A-2244	142	1248/20	4		
ACR24	Sgraffito bowl	A-2244	135	1210/35	4		
ACR25	Sgraffito bowl	A-2244	142	1248/4	4		
ACR26	Sgraffito bowl	A-2244	637	2396/4	4		3
ACR27	Sgraffito bowl	A-2244	634	2407	4		
ACR28	Sgraffito bowl	A-2244	635	2323/17	4		
ACR29	Sgraffito bowl	A-2244	618	2219/1	4		
ACR30	Sgraffito bowl	A-2244	164	1413/12	4		
ACR31	Sgraffito bowl	A-2244	142	1448	4		
ACR32	Sgraffito bowl	A-2244	132	1278/21	4		
ACR33	Sgraffito bowl	A-2244	634	2407/10	4		
ACR34	Slip-painted bowl	A-2244	147	1447/17	6		
ACR35	Slip-painted bowl	A-2244	147	1275/6	6		
ACR36	Slip-painted bowl	A-2244	143	1270/13-1	6		
ACR37	Slip-painted bowl	A-2244	143	1226/4	6		3
ACR38	Slip-painted bowl	A-2244	164	1413/17	6		
ACR39	Slip-painted bowl	A-2244	134	1206/9	6		

* License Nos. G-109/92 and G-52/93: Avissar and Stern 1994; Permit No. A-1763: Hartal 1997; Permit No. A-2244: Syon and Tatcher 1998; Permit No. A-2218: Syon, unpublished

** 1: also sampled by Goren (1997); 2: also sampled by Armstrong and Hatcher (1997:8); 3: sampled for petrography; 4: nothing remained after sampling

Appendix 1: Index of Sampled Sherds (cont.)

Sample No.	Typological Category	License/Permit No.*	Locus No.	Basket No.	Figure	In E.J. Stern 1997	Note**
ACR40	Slip-painted bowl	A-2244	143	1260/15	6		
ACR41	Slip-painted bowl	A-2244	140	1227/5	6		
ACR42	Acre bowl	A-2244	132	1598/13	3		
ACR43	Acre bowl	A-2244	134	1205/1	3		
ACR44	Acre bowl	A-2244	143	1270/13	3		3
ACR45	Acre bowl	A-2244	809	3309/10	3		
ACR46	Acre bowl	A-2244	132	1417/2	3		3
ACR47	Acre bowl	A-2244	809	3304/1	3		3
ACR48	Thick-walled cooking pot	A-2244	808	3124	8		
ACR51	Thick-walled cooking pot	A-2244	808	3374	8		3
ACR52	Thick-walled cooking pot	A-2244	643	2415/4	8		3
ACR53	Thick-walled cooking pot	A-2244	809	3342/1	8		
ACR54	Thick-walled cooking pot	A-2244	618	2215	8		
ACR56	Thick-walled cooking pot	A-2244	132	1328/22	8		3
ACR57	Thin-walled cooking pot	A-2244	142	1252/15	7		
ACR58	Thin-walled cooking pot	A-2244	635	2331/10	7		
ACR64	Slip-painted bowl	G-102/92	13026	130301/1	6		3
ACR65	Slip-painted bowl	G-102/92	13026	130320/1	6		
ACR66	Slip-painted bowl	G-102/92	13028	130327/4	6		
ACR67	Slip-painted bowl	G-102/92	13032	130427/14	6		
ACR68	Slip-painted bowl	G-102/92	13028	130339/2	6		3
ACR69	Slip-painted bowl	G-102/92	13028	130327/18	6		
ACR70	Reserved-slip bowl	G-102/92	13028	130355/7	5		
ACR71	Reserved-slip bowl	G-102/92	13032	130392/19	5		
ACR72	Reserved-slip bowl	G-102/92	13028	130351/21	5		3
ACR73	Zeuxippus Group I	G-102/92	13028	130369/13	10		
ACR74	Reserved-slip bowl	G-102/92	13032	130408/23	5		
ACR75	Reserved-slip bowl	G-102/92	13028	130355/8	5		
ACR76	Reserved-slip bowl	G-102/92	13032	130394/15	5		3
ACR77	Reserved-slip bowl	G-102/92	13028	130381/18	5		3
ACR78	Acre bowl	G-102/92	12031	120940/10	3		
ACR79	Acre bowl	G-102/92	12030	120887/27	3		
ACR80	Acre bowl	G-102/92	12031	120962/5	3		3
ACR81	Thick-walled cooking pot	G-102/92	12022	120392/12	8		
ACR82	Thick-walled cooking pot	G-102/92	12022	120569/16	8		3
ACR83	Thick-walled cooking pot	G-102/92	12025	120455/11	8		3
ACR84	Thick-walled cooking pot	G-102/92	13055	130521/4	8		
ACR85	Thick-walled cooking pot	G-102/92	12027	120749/6	8		3
ACR86	Thick-walled cooking pot	G-102/92	12027	120768/2	8		3
ACR87	Thick-walled cooking pot	G-102/92	12027	120690/13	8		

* License Nos. G-109/92 and G-52/93: Avissar and Stern 1994; Permit No. A-1763: Hartal 1997; Permit No. A-2244: Syon and Tatcher 1998; Permit No. A-2218: Syon, unpublished

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Appendix 1: Index of Sampled Sherds (cont.)

Sample No.	Typological Category	License/Permit No.*	Locus No.	Basket No.	Figure	In E.J. Stern 1997	Note**
ACR88	Thick-walled cooking pot	G-102/92	12027	120986	8		
ACR89	Thick-walled cooking pot	G-102/92	12022	120595	8		
ACR90	Thin-walled cooking pot	G-102/92	13028	130351/6	7		
ACR92	Thin-walled cooking pot	G-102/92	13028	130339/17	7		
ACR93	Thin-walled cooking pot	G-102/92	13028	130359/25	7		
ACR94	Thin-walled cooking pot	G-102/92	13032	130393/6	7		
ACR102	Reserved-slip bowl	G-102/92	13028	130370	5		
ACR103	Acre bowl	G-102/92	12031	120914/3	3		
ACR104	Sgraffito bowl	G-102/92	11029	110356/23	4		
ACR105	Sgraffito bowl	G-102/92	11029	110342/16	4		
ACR106	Sgraffito bowl	G-102/92	11029	110346/6	4		
ACR107	Sgraffito bowl	G-102/92	13043	130567/3	4		
ACR108	Sgraffito bowl	G-102/92	13036	130439/7	4		
ACR109	Slip-painted bowl	G-102/92	13028	130370/4	2:4, 6		
ACR110	Slip-painted bowl	G-102/92	13028	130327/2	6		
ACR111	Slip-painted bowl	A-2244	109	1073/1	-		4
ACR112	Slip-painted bowl	A-2244	122	1178	-		4
ACR113	Slip-painted bowl	A-2244	128	1238	-		4
ACR114	Reserved-slip bowl	G-102/92	13028	130346/2	5		
ACR115	Reserved-slip bowl	G-102/92	13028	130355/1	2:3, 5		
ACR116	Reserved-slip bowl	G-102/92	13039	130506/1	5		
ACR117	Reserved-slip bowl	G-102/92	13032	130393/2	5		
ACR118	Reserved-slip bowl	G-102/92	13039	130507/2	5		
ACR119	Reserved-slip bowl	G-102/92	13039	130507/1	5		
ZW1	Zeuxippus group I	G-102/92	13028	130355/3	10		3
ZW2	Zeuxippus group I	G-102/92	13032	130411/2	10		
ZW3	Zeuxippus group I	G-102/92	13028	130370/3	10		3
ZW4	Zeuxippus group I	A-2244	132	1191/12	10		
ZW5	Zeuxippus group I	A-1763	130	1240/1	10	Fig. 11:81	
ZW6	Zeuxippus group I	A-1763	112	1096/1	10	Fig. 11:83	3
ZW7	Zeuxippus group I	A-1763	136	1239/1	10	Fig. 11:84	
ZW8	Zeuxippus group I	A-1763	106	1112/1	10	Fig. 11:85	
ZW9	Zeuxippus group I	A-1763	111	1087/2	10	Fig. 11:86	
ZW10	Zeuxippus group I	A-1763	122	1172/3	10		3
ZW11	Zeuxippus group II	A-2244	831	3461	11		3
ZW12	Zeuxippus group II	A-2244	648	2481/29	11		
ZW13	Zeuxippus group II	A-2244	723	3162/8	11		3
ZW14	Zeuxippus group II	A-2218	22	163/6	9:2, 11		
ZW15	Zeuxippus group II	G-52/93	16019	160239/1	11		3
ZW16	Zeuxippus group II	G-102/92	14015	140122	11		

* License Nos. G-109/92 and G-52/93: Avissar and Stern 1994; Permit No. A-1763: Hartal 1997; Permit No. A-2244: Syon and Tatcher 1998; Permit No. A-2218: Syon, unpublished

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Appendix 1: Index of Sampled Sherds (cont.)

Sample No.	Typological Category	License/Permit No.*	Locus No.	Basket No.	Figure	In E.J. Stern 1997	Note**
ZW17	Zeuxippus group II	A-1763	103	1018/2	11	Fig. 12:94	
ZW18	Zeuxippus group II	A-1763	104	1046/1	11	Fig. 12:88	3
ZW19	Zeuxippus group II	A-1763	128	1229/5	11		
ZW20	Zeuxippus group III	G-102/92	13047	130692/2	12		3
ZW21	Zeuxippus group III	A-2244	723	3186/16	12		
ZW22	Zeuxippus group IV	A-2244	728	3259/32	13		3
ZW23	Zeuxippus group IV	A-2244	809	3337	13		3
ZW24	Zeuxippus group IV	A-2244	134	1173	13		
ZW25	Zeuxippus group IV	A-2244	728	3243/12	13		3
ZW26	Zeuxippus group IV	A-2244	723	3174/25	13		
ZW27	Zeuxippus group II	A-2244	723	3189/9	11		
ZW28	Zeuxippus group II	A-2244	723	3198/33	11		
ZW29	Zeuxippus group II	A-2244	624	2221/A	11		
ZW30	Zeuxippus group II	A-2244	723	3168/18	11		
ZW31	Zeuxippus group II	A-2244	723	3168/8	11		
ZW33	Zeuxippus group III	A-2244	723	3190/11	12		
ZW34	Zeuxippus group III	A-2244	707	3053	12		
ZW35	Zeuxippus group III	A-2244	723	3192/1	12		
ZW36	Zeuxippus group III	A-2244	723	3191/26	12		
ZW37	Zeuxippus group III	A-2244	723	3162/42	12		
ZW38	Zeuxippus group III	A-2244	809	3349/16	9:3, 12		
ZW39	Zeuxippus group IV	A-2244	147	1305/11	13		
ZW40	Zeuxippus group IV	A-2244	147	1299/11	13		
ZW41	Zeuxippus group IV	A-2244	147	1299/9	9:4, 13		
ZW42	Zeuxippus group IV	A-2244	723	3164/17	13		
ZW43	Zeuxippus group IV	A-2244	723	3174/23	13		

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