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Cross-Cultural Craft Interaction: The Late Bronze Egyptian Garrison at Beth Shan

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Beth Shan, strategically located at the juncture of the Jordan and Jezreel Valleys where major trade routes intersected, was architecturally restructured in the 13th c. B.C. as the most important Egyptian base in Palestine. Following the arrival of Egyptian craftsmen at the site, the archaeological and technological evidence provides a unique perspective on how a deliberate imperialistic policy can affect local ceramic traditions, including pottery and silicate industries. The Egyptians appear to have controlled the industries at their most basic levels—the preparation and supply of raw materials, heavily-tempered clays and faience. The Palestinian ceramic specialists, whether voluntarily or as a forced response, then adapted their techniques and were most likely responsible for technological and stylistic innovations.

Egypt reinitiated significant contact with the Levant, following a hiatus of several centuries, around 1750 B.C. with the rise of Semitic "Hyksos" dynasties in the Nile Delta. The movement of goods and people back and forth between Africa and Western Asia must have been considerable, to judge from the similarity in the material cultures of the two areas.

Following the return of native Egyptians to power ca. 1550 B.C. at the beginning of the Late Bronze Age (LBA), Palestine appears to have assumed a more subservient role to Egypt as a forward defensive position and erstwhile client state.[1] The 13th c. B.C. marks the highpoint of Egyptian influence in Palestinian affairs. Earlier in the LBA, Egyptian pharaohs had been content with a poorly controlled vassalage system, dependent on the loyalty of native dynasts, the presence of small contingents of Egyptian officials and soldiers, and periodic military campaigns. Under the leadership of the powerful rulers of the 19th Dynasty, Sety I and Ramesses II, Egyptian policy was redirected in the 13th c. B.C. toward creating a true colony, with a large Egyptian bureaucracy and military to control the local population and economy.[2] Unlike Nubia (south of the first cataract of the Nile), however, where a small local population offered little resistance, the Egyptian way of life could not be imposed easily on the relatively advanced, populous Palestinian city-states.

Of the many communities in Palestine impacted by Egyptian imperialistic policy, Beth Shan underwent the most profound changes.[2] The 13th c. B.C. levels (VII and VIII) at the site were transformed into an Egyptian military base by dismantling and leveling the earlier LB level (IX) and then constructing typical Egyptian New Kingdom buildings—a residential sector of courtyard house laid out along a grid pattern of streets, a temple, and the so-called migdol ("fortress") and "commandant's house."[3] The shift from Palestinian to Egyptian architectural styles is also reflected in the relative percentage of Egyptian pottery and object types to Palestinian types: approximately 25%, probably the highest percentage ever been recorded at a Palestinian site. At least two monumental stelae of Sety I and one of Ramesses II[4] from Beth Shan are particularly important, since they detail Egyptian military activity in the area, including the defense of the garrison against belligerent city-states (Pella and Hamath, located several kilometers to the south) and peoples (e.g., the *'apiru*, possibly to be identified with the early Hebrews).

Before Beth Shan was excavated, its importance as an Egyptian military base could hardly have been anticipated. It is located far inland along the northeastern frontier of Palestine, over 250 kms. in distance from the Egyptian border. Yet, the site is strategically located at the eastern terminus of the main inland route from the coast; here, where the Jezreel and Jordan Valley meet, routes to southern Syria and Jordan branched off after crossing the Jordan River by a shallow ford.

Even after the wholesale restructuring of Levels VII and VIII by the Egyptians, the local population was not uprooted and moved elsewhere. There is ample artifactual evidence, based on areal calculations of domestic dwellings containing Palestinian-style artifacts, that the bulk of the population on the tell were Canaanites, perhaps about 1500 individuals out of a total population of 2000. The Canaanites who lived alongside the 500 or so Egyptians most likely provided the basic manual and specialized labor needs of the garrison. Some of the Canaanites might even have held very responsible positions in the hierarchy, as earlier reported in the Amarna Letters.[5] In general, however, Egyptians must have occupied most of the important military and administrative posts. Egyptian architects were also present, since they describe themselves as such in inscriptions from the site. Moreover, only a very exact knowledge of Egyptian building techniques can explain the similarity of the garrison layout and individual building types to New Kingdom Egyptian architecture.

Although not specifically referred to in inscriptions, Egyptian craftsmen probably also took up residence at the site. Černý[6] has argued that Egyptian building projects, such as the Theban royals tombs, could not have absorbed all the young men trained in their fathers' trades, so that some always went abroad. The construction of a garrison *de novo* would have especially required the services of stone masons; their presence is substantiated by T-shaped doorsills and lotus capitals of Egyptian style, in addition to the carefully executed figures and hieroglyphic inscriptions on the royal stelae (above), which were made from local basalt. Similarly, considering the numerous Egyptian-style ceramic artifacts from Levels VII and VIII, Egyptian potters and faience-makers probably operated workshops at Beth Shan; certainly, Egyptian material culture could be more expeditiously duplicated by on-site production rather than by importation. At the same time, the output of local Palestinian craftsmen, especially ceramic specialists, does not appear to have diminished. Some crafts (e.g., metalworking, the making of bone and ivory inlay, and the alabaster industry), on the other hand, appear to be almost exclusively the domain of Palestinian craftsmen and to have no Egyptian counterpart at the site.

Theoretical Framework

The proximity of several crafts representing and/or combining different technological traditions in Levels VII and VIII at Beth Shan represents a rare opportunity in the ancient world to examine the extent and directionality of craft interaction. Although limited to a case study of one site at a specific time, the available evidence can only be comprehended within a larger context, and in turn bears significantly on broader theoretical issues.

A plausible theoretical framework is that the technological and stylistic traditions of a dominant economic and political power (Egypt in this instance) are transmitted more readily to a subordinate society (the Palestinian city-state of Beth Shan) rather than vice versa. According to this model, craftsmen of the lesser power would have a greater incentive, if not compulsion, to replicate styles of the dominant group, which could best be achieved by employing the techniques of the latter. Thus, in modern times (since the Renaissance), the transmission and emulation of Western culture has been almost inevitable consequence of colonization. The diffusion of ceramic traditions is one manifestation of this trend, as documented in the ethnoarchaeological literature.[7,8] Borrowing, however, need not be unidirectional (the modern craze in the West for "primitive" art should dispel that notion), and the various groups that comprise an exchange network are selective in what they adopt.[9] In adopting a technique or style, a receptive group or individual may well have to adapt it to different cultural norms and environmental conditions, thereby providing the context and stimulus for innovation.[10,11] Depending upon the systemic interrelationships of the many cultural and environmental factors,[12–14] a more advanced technique eventually will be adopted, once its economic and other social advantages have been recognized and any threat to the existing power structure minimized.[15–17] Other scenarios, though, cannot be excluded, as demonstrated by the oft-cited conservatism of pottery manufacture.[7,13,14]

Synchretistic Cult

From a general cultural perspective, the Level VII/VIII temple precinct and its deposits best illustrate how Egyptian and Palestinian concepts might be combined together. First constructed in Level VIII (assigned to the reign of Sety I) and successively rebuilt in Levels VII

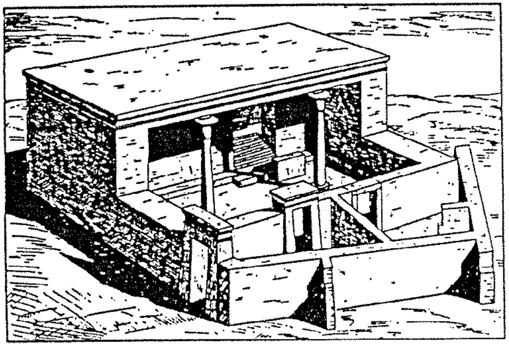

Fig. 1. A reconstruction of the Level VII temple (after fig. 3 in Ref. 4), as based on the excavated evidence and New Kingdom Egyptian architectural analogues. The stairway in particular, flanked by an altar at its top and bottom and leading up to the back sanctuary, is characteristic of New Kingdom Egyptian temples, but would be out of place in contemporaneous Palestinian temples. (Drawing: courtesy of University Museum.)

(Ramesses II) and VI (Ramesses III), the temple was comprised of a lotus-columned inner courtyard, with a stairway leading up to a back altar room (Fig. 1). Its layout is almost identical to mortuary chapels and sanctuaries at Akhenaten's capital of el-Amarna[18] and at the workmen's village of Deir el-Medineh, near the southern capital of Thebes.[19]

Although the temple belongs to an Egyptian architectural type (possible derived at an earlier date from the tripartite and/or *Breitbau* temple of Syria/Palestine), the artifacts recovered from it attest to a combined Egyptian/Canaanite cult. Dedicatory stelae from Levels VII and VIII temple are the most important sources of information about the gods and goddesses who were worshipped. The Mekal stela,[4] which was found in the Level VII/VIII temple precinct, shows a seated, bearded figure, who holds a *was* scepter and *'ankh* sign. The figure, wearing a collar and a conical headdress with two horns at the front and a pair of long streamers at the back, is approached by two males, who hold lotus scepters and wear Egyptian wigs. The accompanying hieroglyphic inscription identifies the seated figure as Mekal, "the god, the lord of Beth Shan," who is invoked by the Egyptians Amenemopet and Paraemheb to give "life, prosperity and health, keen vision, honor and love, a prosperous mouth, the footstep [in its] place, [until] thou reachest a venerated state in peace" (as translated by Rowe). From other Syro-Palestinian and Egyptian representations and inscriptional evidence, Mekal was evidently the local equivalent of a principal Palestinian deity, probably 'El,

Resheph or Baal, who, in turn, were identified with the Egyptian deities, Ptah, Montu, and Seth, respectively.[5] Since the name "Mekal" is from a Semitic root, possibly even related to the later Phoenician Mekel or Melqart, a Canaanite referent for the deity was clearly intended. Egyptian deities are not mentioned as such, but the Egyptian accoutrements of the god on a stela of standard Egyptian type support this interpretation.

Principal female deities were usually coupled with male gods in Syro-Palestinian religion. A stela,[4] which was found leaning up against a basin or bin built into the southwestern corner of the inner courtyard of the Level VII temple, shows a standing female figure in Egyptian pose, who wears a long gown, collar, and *atef* crown, and carries a lotus scepter and *'ankh* sign. A smaller, female figure, wearing a long gown and with a lotus on her wigged head, offers another lotus to the larger figure. The painted hieroglyphic signs on the stela were illegible, but the attributes of the larger figure are definitely divine. Lacking an accompanying inscription, the identity of the Level VII goddess is uncertain, but because of her similarity to Antit on the Level V stela, she was probably the local equivalent of one of the principal Canaanite goddesses ('Ashtarte, 'Asherah, 'Elat, Baalat, Qudshu, etc.), who often interchanged roles.

The principal Canaanite goddesses were very often identified with Hathor, the Egyptian goddess of foreign countries and the "Lady of Turquoise." A "clapper" or wand (Fig. 2), a *menat* (the counterpoise at the back of large Egyptian necklaces or collars), and a mounted gold-covered head of this goddess were recovered from the Level VII temple. Female pottery figurines of both Syro-Palestinian and Egyptian types from the temple probably also represent a Canaanite goddess, Hathor, or a combination of the two.

While Hathor might have been especially honored in the temple, it is doubtful that an Egyptian Hathor ritual with dance festivals was carried out there. The presence of only one "clapper" or wand, when two would have been needed for clapping above the head of the priest, suggests that it only signified the goddess or benefits conferred by her. Nevertheless, the concentration of other Egyptian-style objects in the temple, with cultic associations in New Kingdom Egypt, points to a temple service very much influenced by Egyptian practice. For example, bowls with duck or goose heads attached to their rims were probably used to present temple offerings. They were often set on tall cylindrical stands, many fragments of which were recovered from the Level VII/VIII temple, like the stand supporting a bowl between the pharaoh and Re-Harmachis on one of the Sety I stela. So-called "flower pots" and "beerbottles," distinctive Egyptian pottery vessels, might also have been employed in a New Kingdom bread and beer *(htp di nsw)* ritual.

Because of the lack of contemporaneous textual evidence, Canaanite religious practice is poorly understood. A major feature of most LB Syro-Palestinian temples, unlike those in Egypt, was an altar for burnt animal offerings in an outer courtyard. A large altar, strewn about with ashes and numerous charred animal bones, in the northern outer courtyard of the Level VII temple, provides evidence

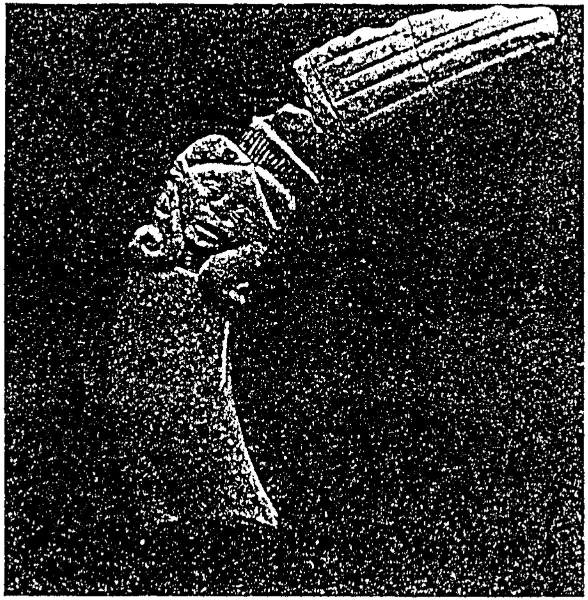

Fig. 2. Hathor "clapper" or wand (field nos. 25.11.192 and 25.11.698-699; University Museum nos. 29-105-217 and 29-105-267/268) of hippopotamus ivory, showing the popular Egyptian goddess of love, joy, turquoise, and foreign lands full-faced, with cow's ears, a spiralling wig, a probable multistringed collar, and a fluted crown or bracelet above the wig. The curved, terminal end of the piece ends in a fully extended right hand. (Photograph: courtesy of University Museum.)

that burnt offerings were part of the ritual carried out in the Beth Shan temple. The practice of burying special objects as ex voto or foundation deposits under walls, floors, and, in the case of the Level VII/VIII temple, under the steps leading up to the sanctuary (Fig. 3), is also characteristically Canaanite. Even most of the Egyptian-style artifacts were treated in this fashion.

Evidence for Technological Interaction/Exchange

If the local Palestinians and immigrant Egyptians had no inherent difficulty in combining religious iconography and practice (although it is uncertain to what extent a borrowed concept or motif would have been recast so as to be more compatible with native belief and practice), then a similar sharing of technological expertise might be anticipated to have occurred at the site.

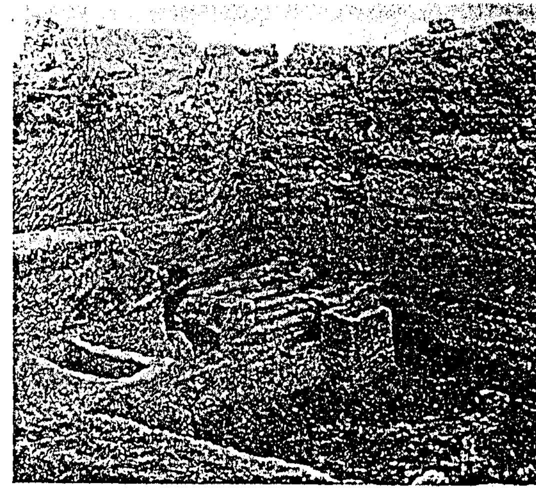

Fig. 3. The stairway of the Level VII temple as it appeared after excavation in 1925. It concealed a large hoard of Egyptian-style glass and faience vessels, jewelry, scarabs, cylinder seals, and other special objects, which had been deposited there as votive or foundation offerings. (Photograph: courtesy of University Museum.)

Pottery Artifacts*

A notable example of both religious, stylistic, and technological exchange involves pottery cobra figurines, probably to be equated with an Egyptian cobra god, such as Mert Seger or Ranout, and pottery plaque figurines of naked females, most often representing a Canaanite fertility goddess (Fig. 4). Both artifact types were very prevalent in the Level VII/VIII temple. The cobra figurines were handmade by pressing or attaching separate pieces of clay: a

*Since only finished pottery was available for study and there was minimal evidence of a local industry (e.g., probable potter's tools and the lower half of a tournette or wheel), complementary analytical techniques were required to reconstruct the industrial sequence from raw material preparation through formation and surface decoration to firing (Ref. 20). A routine procedure (Ref. 21) for analyzing a group of finished pottery has been developed at the Museum Applied Science Center for Archaeology (MASCA), and the 60 Beth Shan specimens underwent a series of analyses, including xeroradiography, petrography, refiring, scanning electron microscopy (SEM), proton-induced x-ray emission spectroscopy (PIXE), and neutron activation (NAA). The analytical procedures, alone or in combination, provide information about the production stages, e.g., the provenience and preparation of clays and tempers (petrography and neutron activation), fabrication methods (xeroradiography), surface decorations (SEM and PIXE), and the original firing temperature range (refiring, petrography, and SEM).

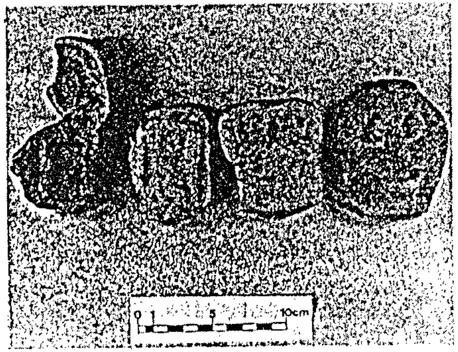

Fig. 4. (*a–d*) The mold fragment (field no. 27.12.2; University Museum no. 29-103-940) of the head and upper torso of a female (*a*) was probably used to make the figurine fragment (*b*; field no. 25.11.544; University Museum no. 29-103-885) from the Level VII temple precinct. The torso (field no. 27.11.44; University Museum no. 29-103-890) of another female figurine (*c*), on the other hand, was constructed by hand from a slab of clay onto which were applied wads and coils of clay as breasts and arms. From a manufacturing point of view, the handmade figurine is most similar to torsos of cobra figurines (*d*; field no. 27.10.818, University Museum no. 29-103-915), several of which have applied breasts. The significance of the cup-like feature below the breasts is uncertain; it also occurs on Egyptian examples, but, so far as is known, never in conjunction with breasts. The coalescence of the stylistic and fabrication features of the Beth Shan female and cobra figurines points to an amalgamation of religious and technological concepts at the site. Examples *a* to *d* are ordered from left to right. (Photograph: P. McGovern.)

modelled head, a flattened slab for the characteristic broad throat of the cobra, and a base slab with an applied coil or built-up wads as the tail, into which the torso slab was inserted. Three cobra figurines, however, were unique to Beth Shan in having breasts depicted by applied clay pellets. This feature pointed to an amalgamation of an Egyptian snake goddess with a principal Canaanite female deity. Corroborating this interpretation was a female figurine plaque which was fabricated like the cobra figurines; rather than being mold-made as every other female figurine, its torso was a flat slab to which clay pellets were applied as breasts and side rolls of clay as arms.[22]

Compositional Analysis[23]*:* Although a composite type, such as the snake/female figurine, might be anticipated to have been manufactured from local clay at Beth Shan, the initial expectation was that

Table I. Neutron Activation Analysis of Beth Shan pottery artifacts

	Na_2O %	K_2O %	Rb_2O PPM	Cs_2O PPM	BaO PPM	Sc_2O_3 PPM	La_2O_3 PPM	CeO_2 PPM	Eu_2O_3 PPM	Lu_2O_3 PPM	HfO_2 PPM	ThO_2 PPM	Ta_2O_5 PPM	Cr_2O_3 PPM	MnO PPM	Fe_2O_3 %	CoO PPM	Sb_2O_3 PPM	CaO %	ZnO PPM	Sm_2O_3 PPM	Yb_2O_3 PPM	SrO PPM
PMBS01	0.450	2.24	42.9	1.45	417	17.6	30.3	61.0	1.36	0.410	4.66	6.90	6.38	154	259	4.58	16.3	0.491	25.6	117	5.75	2.27	783
PMBS02	0.519	1.82	25.9	0.95	303	12.2	19.1	43.0	0.95	0.297	4.25	4.73	1.19	81	275	3.49	10.3	NR	31.3	NR	3.99	1.64	719
PMBS03	0.594	2.07	21.3	1.09	311	14.0	23.2	52.0	1.16	0.230	4.42	5.09	1.22	90	263	2.88	7.8	NR	27.2	175	4.63	1.55	499
PMBS04	0.671	2.42	32.2	1.28	249	15.9	25.2	51.6	1.17	0.357	5.25	5.45	NR	100	423	4.40	15.2	NR	28.1	NR	4.63	1.87	436
PMBS05	0.501	2.04	36.0	1.29	251	12.5	19.6	42.0	1.03	0.293	4.59	4.61	1.02	82	323	3.54	9.9	NR	33.9	294	4.15	1.68	624
PMBS06	0.574	2.18	43.6	1.86	259	15.6	24.3	54.2	1.24	0.370	5.04	5.51	1.19	104	397	4.32	12.6	0.257	33.6	312	5.12	2.05	547
PMBS07	0.413	2.15	22.4	1.22	2523	21.7	45.8	76.6	2.36	0.721	4.11	5.96	1.44	232	863	5.15	39.0	0.940	26.9	NR	8.81	3.89	558
PMBS08	0.871	2.02	40.2	1.61	390	18.1	27.7	59.8	1.39	0.444	6.49	6.65	1.37	84	379	5.01	16.1	0.210	44.9	NR	5.30	2.32	662
PMBS09	0.360	1.75	41.5	2.03	548	13.5	21.9	46.7	1.15	0.316	4.21	4.53	1.03	102	423	4.01	11.6	NR	28.5	207	5.15	1.66	569
PMBS10	0.387	1.42	36.1	1.82	337	22.3	45.2	74.8	1.91	0.681	4.78	8.75	1.21	275	598	6.19	18.7	1.256	25.4	315	7.18	3.65	746
PMBS11	0.427	1.69	33.1	1.92	216	13.1	23.3	48.9	1.14	0.298	4.81	5.47	1.11	86	321	3.07	8.8	NR	35.6	259	4.67	1.51	484
PMBS12	0.611	1.94	33.0	1.49	1371	24.2	45.2	78.0	2.07	0.679	5.40	7.74	1.24	222	855	5.96	23.7	NR	21.7	NR	7.01	3.65	483
PMBS13	0.424	1.37	28.3	1.03	195	15.2	28.2	53.3	1.29	0.426	4.81	5.37	0.92	200	558	3.73	13.7	NR	35.5	NR	5.40	2.30	540
PMBS14	0.378	1.50	25.5	1.25	254	11.1	18.2	38.1	0.88	0.256	3.88	4.25	0.79	73	207	2.59	7.8	0.185	36.7	10	3.65	1.42	593
PMBS15	0.723	2.28	43.5	1.90	398	17.7	28.6	58.6	1.45	0.402	4.82	6.18	1.38	144	512	5.42	18.7	0.453	27.9	132	5.62	2.31	711
PMBS16	0.519	3.79	81.3	4.12	188	28.6	26.2	47.9	1.26	0.406	4.33	7.52	1.05	131	428	6.05	20.5	0.287	9.4	NR	4.27	2.01	NR
PMBS17	0.752	2.48	22.0	0.61	205	17.3	27.6	60.7	1.46	0.434	5.38	6.04	1.07	68	253	4.47	14.4	NR	34.1	NR	5.90	2.21	1374
PMBS18	0.693	2.18	30.8	1.16	240	13.9	22.0	45.1	1.15	0.313	4.21	5.27	0.83	70	352	3.87	13.2	NR	32.0	NR	4.73	1.79	575
PMBS19	0.776	2.20	27.6	1.11	208	13.6	20.9	44.4	1.01	0.318	6.61	4.69	0.98	86	305	3.60	12.3	0.245	35.2	NR	5.00	1.88	528
PMBS20	1.239	3.03	57.9	2.30	899	22.9	35.3	69.3	1.92	0.399	5.35	6.68	1.56	192	611	6.10	22.5	0.334	23.2	NR	6.82	2.78	802
PMBS21	0.478	1.43	25.2	1.70	182	12.6	19.1	40.4	0.91	0.271	3.96	4.47	0.91	79	253	3.30	10.3	0.180	35.5	NR	3.63	1.56	476
PMBS22	0.767	2.39	34.9	1.08	618	18.5	28.3	57.8	1.51	0.384	5.27	4.70	1.26	143	1002	5.01	23.2	0.207	22.5	NR	5.42	2.11	518
PMBS23	0.508	1.82	32.1	1.63	1702	23.8	47.9	86.9	2.39	0.640	5.51	7.21	2.07	254	1094	6.37	32.3	0.279	19.5	NR	8.32	3.35	574
PMBS24	0.640	2.12	30.5	1.46	229	14.4	22.3	51.9	1.17	0.332	4.52	5.20	1.19	91	328	3.59	12.9	NR	29.5	88	4.91	1.79	465
PMBS25	0.486	1.49	32.5	1.69	223	12.6	18.7	42.6	0.97	0.291	3.82	4.71	1.07	75	251	3.58	10.8	NR	35.3	NR	4.11	1.57	634
PMBS26	0.718	2.77	147.2	7.43	337	38.8	40.8	63.4	1.41	0.488	2.91	11.48	0.36	312	1396	8.07	42.0	NR	12.7	NR	5.15	2.86	362
PMBS27	0.562	3.25	178.2	8.93	646	38.0	40.1	78.3	1.63	0.540	3.40	12.62	1.35	312	1227	7.91	43.7	0.708	12.7	NR	5.78	3.06	393
PMBS28	0.550	3.08	160.3	0.72	306	34.0	38.6	70.0	1.51	0.472	3.19	11.09	0.97	307	1202	7.01	51.9	0.738	10.5	NR	5.82	2.92	147
PMBS29	0.614	2.47	36.0	1.17	333	15.9	25.4	53.3	1.28	0.341	4.27	5.20	1.18	111	490	4.68	15.2	0.290	30.1	NR	5.13	1.81	701
PMBS30	0.776	3.10	153.8	7.06	367	32.7	36.2	66.7	1.35	0.481	3.93	11.78	1.00	286	1047	7.19	33.0	NR	13.1	NR	5.19	2.93	315
PMBS31	0.733	2.78	140.6	7.00	356	32.7	34.8	67.8	1.40	0.454	3.57	10.74	0.89	313	1365	7.10	50.4	0.270	16.4	NR	5.48	2.74	375
PMBS32	0.454	1.42	27.0	1.42	184	11.4	17.7	37.1	0.94	0.249	3.39	3.94	0.84	72	239	2.97	10.2	0.140	6.7	NR	3.50	1.41	258
PMBS33	0.838	3.15	147.9	6.67	437	29.5	50.8	97.9	1.77	0.583	5.20	14.55	1.58	149	1476	7.11	32.2	NR	5.8	NR	7.21	3.23	273
PMBS34	1.368	0.50	NR	NR	144	68.1	8.4	19.1	0.83	0.383	1.62	1.56	0.47	213	1791	10.64	66.7	NR	2.6	NR	2.32	1.60	NR
PMBS35	1.449	2.78	59.2	3.03	321	24.4	22.1	44.9	1.13	0.367	2.88	6.43	0.74	318	1045	4.85	20.0	0.452	25.6	NR	4.42	1.90	514
PMBS36	0.771	3.60	147.6	7.24	1076	28.5	51.3	105.0	1.86	0.596	5.08	5.14	1.93	153	1380	6.84	25.6	0.608	5.3	NR	8.57	3.37	NR
PMBS37	0.333	2.09	24.2	0.97	497	12.0	17.9	38.4	0.88	0.257	3.47	3.94	0.72	77	241	3.48	9.2	NR	34.8	NR	3.92	1.44	652
PMBS38	1.435	0.54	13.6	0.65	116	62.4	9.0	15.7	0.74	0.338	1.63	2.09	NR	144	1614	9.20	52.8	NR	2	NR	2.23	1.28	NR
PMBS39	0.957	3.61	135.2	5.89	331	26.8	41.5	93.3	1.58	0.551	5.13	4.39	1.85	140	1368	6.67	26.4	0.522	4.9	NR	7.19	3.18	484
PMBS40	0.771	0.93	NR	NR	92	71.3	5.3	11.4	0.67	0.505	1.50	1.32	0.38	838	1127	9.10	75.0	NR	NR	NR	2.63	2.78	NR

Table I. (cont'd)

	Na_2O %	K_2O %	Rb_2O PPM	Cs_2O PPM	BaO PPM	Sc_2O_3 PPM	La_2O_3 PPM	CeO_2 PPM	Eu_2O_3 PPM	Lu_2O_3 PPM	HfO_2 PPM
PMBS41	0.962	0.58	11.6	NR	171	71.9	9.0	23.0	0.77	0.414	1.68
PMBS42	0.834	3.66	150.0	8.95	399	28.4	50.4	08.9	1.94	0.630	5.01
PMBS43	2.178	0.79	24.2	2.72	3622	23.8	82.8	66.5	2.12	1.315	1.90
PMBS44	0.504	2.26	65.6	3.42	303	35.9	91.0	86.6	4.17	1.038	13.90
PMBS45	0.239	1.38	36.8	2.18	229	13.1	21.3	47.5	1.14	0.303	3.92
PMBS46	0.662	1.80	32.8	1.79	1762	15.7	26.4	55.7	1.45	0.374	3.86
PMBS47	0.863	2.35	42.5	2.30	360	17.2	28.1	60.1	1.49	0.412	6.11
PMBS48	0.560	1.91	23.2	0.89	265	12.6	20.3	45.4	1.11	0.313	4.20
PMBS49	0.665	2.50	27.4	1.26	495	12.9	22.4	47.8	1.26	0.351	3.84
PMBS50	0.451	1.67	27.3	1.43	272	12.5	19.9	43.7	NR	0.337	4.06
PMBS51	0.394	1.46	49.0	2.16	424	26.3	53.6	86.1	2.14	0.685	5.35
PMBS52	0.536	1.59	44.4	2.07	290	13.7	21.4	45.2	1.04	0.343	4.40
PMBS53	0.610	1.95	28.3	1.30	252	14.3	22.1	49.7	1.14	0.358	4.52
PMBS54	0.656	2.44	41.2	2.51	369	16.3	26.8	38.2	1.24	0.391	5.18
PMBS55	0.604	2.16	37.8	2.00	324	20.1	32.4	67.5	1.62	0.536	6.79
PMBS56	0.574	1.95	30.3	1.80	396	17.1	28.6	58.7	1.49	0.417	5.15
PMBS57	0.429	1.45	26.5	1.75	327	10.4	16.0	35.3	0.84	0.269	3.34
PMBS58	0.429	1.05	31.8	1.92	3228	24.6	97.7	27.5	1.99	1.038<	2.13
PMBS59	0.456	2.04	29.6	1.04	927	11.0	17.7	38.8	0.83	0.300	3.66

	ThO_2 PPM	Ta_2O_5 PPM	Cr_2O_3 PPM	MnO PPM	Fe_2O_3 %	CoO PPM	Sb_2O_3 PPM	CaO %	ZnO PPM	Sm_2O_3 PPM	Yb_2O_3 PPM	SrO PPM
PMBS41	2.00	NR	374	1406	9.31	62.1	NR	NR	NR	2.50	1.62	NR
PMBS42	6.22	2.47	172	1247	6.97	31.8	1.368	NR	NR	8.43	3.25	NR
PMBS43	4.79	0.67	1442	80	6.00	10.3	NR	NR	NR	9.57	6.55	NR
PMBS44	8.11	7.16	256	156	4.33	59.3	0.989	NR	NR	12.59	5.98	NR
PMBS45	5.06	1.25	96	341	3.86	9.9	0.437	NR	NR	4.60	1.08	NR
PMBS46	5.14	1.45	170	603	4.74	23.1	0.107	NR	NR	5.81	2.12	NR
PMBS47	6.52	1.76	135	379	4.71	14.6	0.269	NR	NR	5.40	2.47	NR
PMBS48	4.94	1.20	91	369	3.69	11.2	0.428	NR	NR	4.38	1.96	NR
PMBS49	4.89	1.31	126	873	3.61	13.7	0.244	NR	NR	4.55	2.09	NR
PMBS50	4.88	1.36	83	359	3.28	10.9	0.188	38.2	NR	3.48	1.67	637
PMBS51	10.45	2.02	313	664	5.50	21.4	0.843	27.8	NR	7.28	3.99	951
PMBS52	5.30	1.34	90	316	3.21	10.8	0.246	36.0	NR	3.95	1.41	551
PMBS53	5.64	1.35	96	344	3.97	14.5	0.191	36.0	NR	4.22	1.82	753
PMBS54	6.79	1.49	105	330	3.56	10.0	0.252	27.6	NR	4.70	1.96	428
PMBS55	8.24	1.89	129	290	5.33	15.9	0.377	47.2	NR	5.68	2.36	569
PMBS56	6.25	1.53	138	256	3.94	15.5	0.269	35.5	NR	4.66	2.18	485
PMBS57	4.04	0.86	67	338	2.70	8.1	0.165	44.6	NR	3.04	1.25	618
PMBS58	5.43	1.10	1242	165	5.36	9.3	3.381	19.6	NR	7.59	5.12<	1014
PMBS59	4.60	1.02	77	182	3.03	6.8	0.126	43.4	NR	3.03	1.39	1107

Table II. Neutron Activation Analysis matches for Beth Shan pottery artifacts

1. *Presumed local specimens matching only one another*

NAA No.	Specimen No.	Description	Matches
PMBS01	35	Feline figure	
PMBS02	4	Krater	
PMBS03	17	Cup-and-saucer	
PMBS04	2	Folded bowl	
PMBS05	19	Splayed-rim bowl	
PMBS06	20	Splayed-rim bowl	
PMBS08	40	*Kernos* with miniature storage jar	
PMBS11	1	Bowl	
PMBS14	26	Female figurine mold	
PMBS15	16	Lamp	
PMBS17[1]	14	Pilgrim's flask	
PMBS18	3	Krater	
PMBS19	37	Zoomorphic stand	
PMBS20[2]	13	Goblet	
PMBS21	15	Double pilgrim's flask	
PMBS24	22	Spinning bowl	
PMBS25	8	Strainer jug	
PMBS29	30	Anthropomorphic mask	
PMBS32	25	Female figurine plaque	
PMBS37	28	Anthropomorphic head	
PMBS45	42	Dumbell-shaped object	
PMBS47	18	Ring stand	
PMBS48	33	Cobra figurine	
PMBS50	9	Jar	
PMBS52	23	Female figurine plaque	
PMBS53	31	Duck or goose head	
PMBS54	36	Miniature storage jar from probable donkey figurine	
PMBS55	29	Anthropomorphic head	
PMBS56	24	Female figurine plaque	
PMBS57	43	Uncertain object	
PMBS59	27	Female figurine mold	

2. *Specimens primarily with Palestinian matches*

NAA No.	Specimen No.	Description	Matches
PMBS07	6	Juglet	PMBS23
PMBS09	41	Miniature bowl	PMBS52, Gibeon
PMBS12	11	Storage jar handle	PMBS 23, Tell el-Hesi, Gezer, Tell Beit Mirsim
PMBS13	12	Storage jar	Tell el-Hesi
PMBS16	5	Juglet	Jericho

Table II. (cont'd)

PMBS22	21	Splayed-rim bowl	Ifshar, Tell el-Hesi, Gezer
PMBS23	7	Strainer jug spout	PMBS07, PMBS12 Shegef, Jericho
PMBS46	32	Cobra figurine	Tell Beit Mirsim
PMBS49	39	Anthropomorphic head appliqué on cylindrical stand	PMBS29, Ifshar, Beth Shemesh

3. *Specimen with Syrian matches*

NAA No.	Specimen No.	Description	Matches
PMBS10 and PMBS51	10	Storage jar	Tell Arqa, Hama, Tell el-Dab'a Syrian wares

4. *Mycenaean IIIA2 and IIIB imported specimens*

NAA No.	Specimen No.	Description	Matches
PMBS26	48	Small juglet	Mycenae, Laconia
PMBS27	50	Shallow cup	Mycenae
PMBS28	49	Small jug	Mycenae, Laconia
PMBS30	46	Amphoroid krater	Mycenae
PMBS31	47	Probable globular stirrup jar	Mycenae, Laconia, Kythera

5. *Cypriot Base Ring I and II imported specimens*

NAA No.	Specimen No.	Description	Matches
PMBS33[3]	51	Bowl	Melissa, Vounari, Phlamoudhi, Baq'ah Valley
PMBS36	52	Juglet handle	Kition, Idalion
PMBS39	53	Jug	Baq'ah Valley, Domuz Tepe, Sirkeli, Phlamoudhi
PMBS42	54	Jug handle	Vounari, Baq'ah Valley, Domuz Tepe, Phlamoudhi

6. *Cypriot White Slip II imported specimens*

NAA No.	Specimen No.	Description	Matches
PMBS34	55	Milk bowl	PMBS38, PMBS41, Phlamoudhi
PMBS38[4]	56	Milk bowl	PMBS34

Table II. (cont'd)

PMBS41	58	Milk bowl handle	PMBS34, Ayios Stephanos "Ambelia"

7. *Specimens of uncertain provenience*

NAA No.	Specimen No.	Description	Matches
PMBS35	60	White shaved juglet	None
PMBS40	57	White Slip II milk bowl	None
PMBS43	44	Glazed jar	None
PMBS44	45	Glazed bowl	None
PMBS58	34	Bull's head from rhyton	None

[1]No matches at a mean Euclidean distance of 0.10, but according to the Adsearch, the specimen has a 58.8% probability of belonging to the presumed local group.
[2]The specimen only matches a Palestinian type from Tell ed-Dab'a in Egypt, but the XADSEARCH gives it a 65.1% probability of belonging to the presumed local group.
[3]This specimen also has close relationships with samples of probable Cypriot origin from Tyre, Aegina, Domuz Tepe, and Sirkeli.
[4]Although weakly supported, the specimen is probably of Cypriot origin.

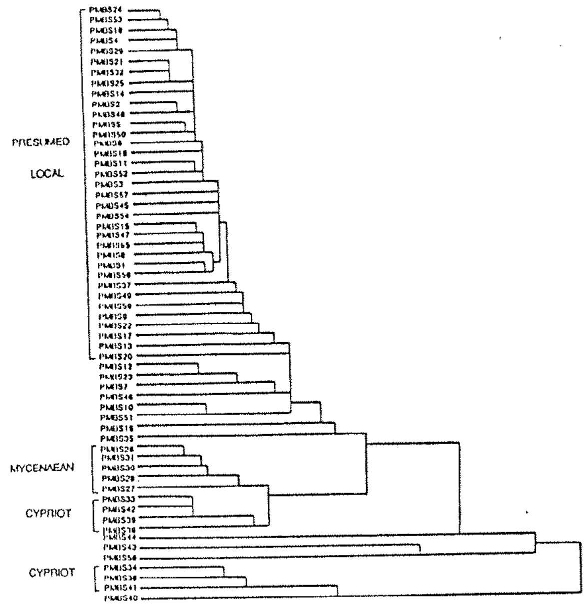

Fig. 5. Dendrogram of Beth Shan pottery specimens.

some of the other Egyptian-style pottery vessels and special objects from Levels VII and VIII were imported. It was somewhat surprising then to discover that *all* the Egyptian-style pottery specimens chemically analyzed by NAA† clustered closely with a large group of Palestinian pottery specimens (Tables I and II; Fig. 5). On the dendrogram (Fig. 5), Mycenaean pottery, glazed pottery ware, and two Cypriot pottery clusters are very distinct from the presumed local group. The Brookhaven data bank includes a large group of modern and ancient Nile alluvium samples, and these clays have very different compositions and clustered totally apart from the Beth Shan specimens.

The presumed local pottery forms and object types are not segregated from one another, but rather are randomly intermixed on the dendrogram. A small grouping at the bottom of the presumed local cluster, which is comprised of one special object and four Palestinian vessel types (PMBS12, PMBS23, PMBS07, PMBS46, and PMBS10/PMBS51, specimen nos. 11, 7, 32, and 10, respectively, in Table III) might appear to be an exception. The petrographic data, however, suggests that this grouping may be partly the result of the presence of heavy igneous minerals. Specimens of the main group (e.g., PMBS20, PMBS22, and PMBS49; nos. 13, 21, and 39), which are close to this grouping, are also relatively higher in igneous inclusions. Another possibility, which will be more fully discussed below, is that members of this grouping are imports.

Two outliers from the main groups on the dendrogram (PMBS16 and PMBS35; nos. 5 and 60) are related to the presumed local group and one of the Cypriot subgroups, respectively. The bull figurine head (PMBS58; no. 34) clusters closely with the glazed pottery specimens (PMBS43 and PMBS44; nos. 44 and 45); its depleted mineralogy, which is unique to the special object group, is in fact most comparable to that of the glazed pottery.

Although the main groups are well substantiated, some of the outlying specimens, including the small presumed local grouping, could be "artifacts" of the statistical analysis. The dendrogram is a two-dimensional projection of the Euclidean distances between data points in multidimensional space (generated by a hierarchical aggregative clustering algorithm). The inherent simplification of the relationship between specimens on the dendrogram may be reflected in some specimens appearing to be more chemically diverse or similar than they actually are[25] (also see Ref. 24). The inclusion of the alkalis (sodium, potassium, rubidium) and the alkaline earths (calcium, barium), in particular, can produce significant deviations in the analysis, since these elements are readily leached out and redeposited in pottery wares by groundwater and their measured compositions can therefore differ from that in the original ware. Variation, yet to be explained, has also been observed for other elements (e.g., lanthanum, manganese, samarium). Covariance between elements, on the other hand, would accentuate clustering.

†Apart from two specimens (nos. 38 and 59), the entire group was tested by NAA at Brookhaven National Laboratory, and individual specimens are denoted by NAA reference numbers in the catalogue (the acronym PMBS denotes the first initials of the author and Beth Shan). The analytical procedures have been fully described elsewhere (Ref. 24). Briefly, samples were drilled from the interior fabric with a tungsten-carbide drill, thus minimizing near-surface contamination. Clays were homogenized, fired to ca. 700°C, dried at 100°C, and then precisely weighed into "Suprasil" quartz ampoules. Samples were then subjected to two irradiations at a flux of 1×10^{14} neutrons/cm^2·sec: (1) a ten second bombardment to activate sodium, potassium, and manganese, with one hour cooling time; and (2) a four hour bombardment to activate 20 longer-lived elements, with a 10 day cooling. Six United States Geological Survey rocks (DTS-1, PCC-1, AGV-1, BCR-1, G-2, and GSP-1) served as standards. The resultant data were then processed by an in-house computer program "INTRAL," incorporating decay corrections, spectrum analyses, and the USGS standards, which yielded oxide concentrations of the 23 elements for each specimen (Table I).

Table III. Analytical corpus of Beth Shan pottery artifacts

I. *Presumed local specimens*

a. Palestinian vessel forms

1. Bowl (field no. 27.9.285; Museum no. 29-102-395; PMBS11)
Mineralogy: calcite (silt- and sand-sized, ca. 4%), quartz (silt-sized, ca. 3%), chert (1%), plagioclase, opaques, unidentified rock (ca. 1%), oolites, no nodules, some organic material.

2. Folded Bowl (field no. 25.11.254; Museum no. 29-102-484; PMBS4)
Mineralogy: calcite (silt- and sand-sized, ca. 8%), quartz (silt-sized, ca. 7%), clinopyroxene, epidote, green hornblende, opaques, plagioclase, unidentified fossil, algal limestone, no nodules, organic material (ca. 3%).

3. Krater (field no. 27.10.759; Museum no. 29-103-627; PMBS18)
Mineralogy: calcite (silt- and sand-sized, ca. 0.3%), quartz (silt-sized, ca. 0.2%), plagioclase (ca. 0.1%), biotite, clinopyroxene, epidote, opaques, unidentified fossil, no nodules.

4. Krater (field no. 25.11.636; Museum no. 29-103-603; PMBS2)
Mineralogy: calcite (silt- and sand-sized, ca. 4.5%), quartz (silt-sized, ca. 3.5%), clinopyroxene, plagioclase, opaques, shell fragments, unidentified fossil, rare nodules.

5. Juglet (field no. 27.10.493; Museum no. 29-102-771; PMBS16)
Mineralogy: quartz (silt- and sand-sized, ca. 4%), calcite (silt- and sand-sized, ca. 1%), clinopyroxene?, nodules (<1%), organic material (<1%).

6. Juglet (field no. 25.11.288; Museum no. 29-102-716; PMBS7)
Mineralogy: calcite (silt- and sand-sized, ca. 2.5%), quartz (silt-sized, ca. 1.5%), clinopyroxene, epidote?, limestone fragments, opaques, few nodules.

7. Strainer Jug spout (field no. 27.11.104; Museum no. 29-103-134; PMBS23)
Mineralogy: calcite (silt- sand-sized, ca. 4%), quartz (silt-sized, ca. 1%), clinopyroxene, opaques, plagioclase, foraminiferal fragments, unidentified fossil, nodules (2-3%).

8. Strainer Jug (field no. 28.10.131; Museum no. 29-103-125; PMBS25)
Mineralogy: calcite (silt- and sand-sized, ca. 11%), quartz (silt-sized, ca. 2%), clinopyroxene, epidote, muscovite, plagioclase, oolites, shell fragments, no nodules.

9. Jar (field no. 25.11.144; Museum no. 29-103-155; PMBS50)
Mineralogy: calcite (silt- and sand-sized, ca. 8%), quartz (ca. 5%), clinopyroxene, epidote, green hornblende, muscovite, opaques, unidentified fossil, shell fragments, no nodules, some organic material.

10. Storage Jar (field no. 27.11.124a-h; Museum no. 29-103-505; PMBS10 and PMBS51)
Mineralogy: calcite (silt- and sand-sized, 8%), quartz (silt-sized, 8%), basaltic hornblende, chert, clinopyroxene, opaques, plagioclase, two unidentified fossils, shell fragments, nodules (ca. 2%).

11. Storage Jar handle (field no. 27.10.739; Museum no. 29-103-205; PMBS12)
Mineralogy: calcite (silt- and sand-sized, ca. 2.5%), quartz (silt-sized, ca. 1.5%), igneous rock fragments (ca. 0.1%), aegerine-augite?, cassiterite?, clinopyroxene, epidote, hypersthene?, microcline, muscovite, rare nodules.

12. Storage Jar base and sidewall (field no. 27.10.610; Museum no. 29-103-362; PMBS13)
Mineralogy: calcite and foraminiferal fragments (silt- to granule-sized, ca. 5.5%), quartz (silt-sized, ca. 1.5%), chert, epidote?, feldspar?, opaques, shell fragments, no nodules.

13. Goblet (field no. 26.9.143; Museum no. 29-103-154; PMBS20)
Mineralogy: calcite (silt- and sand-sized, ca. 3.5%), quartz (silt-sized, ca. 3%), clinopyroxene (ca. 0.1%), plagioclase (ca. 0.1%), igneous rock fragments (ca. 0.1%), chert, epidote?, opaques, no nodules.

14. Pilgrim's Flask (field no. 27.10.564; Museum no. 29-102-836; PMBS17)
Mineralogy: calcite (silt- and sand-sized, ca. 9.5%), quartz (silt-sized, ca 8.5%), basaltic hornblende, biotite, clinopyroxene, epidote?, plagioclase, no nodules.

15. Double Pilgrim's Flask (field no. 27.10.767; Museum no. 29-102-881; PMBS21)
Mineralogy: calcite (silt- and sand-sized, ca. 1.5%), quartz (silt-sized, ca. 0.5%), apatite?, clinopyroxene?, clinozoisite?, microcline, muscovite, opaques, plagioclase, zircon?, shell fragment, unidentified fossil, no nodules.

16. Lamp (field no. 27.10.575; Museum no. 29-102-348; PMBS15)
Mineralogy: calcite (silt- and sand-sized, ca. 4.5%); quartz (silt-sized, ca. 3.5%), epidote, muscovite, opaques, plagioclase, unidentified fossil, nodules (<1%).

17. Cup-and-Saucer (field no. 26.11.36; Museum no. 29-102-370; PMBS3)
Mineralogy: quartz (silt-sized, ca. 0.4%), calcite (silt- and sand-sized, ca. 0.1%), clinopyroxene?, epidote?, opaques, no nodules, organic material (<1%).

18. Ring Stand (field no. 28.10.326; Museum no. 29-103-328; PMBS47)
Mineralogy: calcite (silt- and sand-sized, ca. 3%), quartz (silt-sized, ca. 2%), biotite, clinopyroxene, epidote, microcline, unidentified rock, oolites, nodules (<0.5%).

b. Egyptian-style vessel forms

19. Splayed-rim Bowl (field no. 27.9.296; Museum no. 29-102-388; PMBS5)
Mineralogy: quartz (silt-sized, ca. 0.7%), calcite (silt- and sand-sized, ca. 0.3.%), epidote (ca. 0.2%), muscovite, opaques, plagioclase, two unidentified rocks, unidentified fossil, shell fragments, no nodules.

20. Splayed-rim Bowl (field no. 27.9.291; Museum no. 29-102-382; PMBS6)
Mineralogy: calcite (silt- and sand sized, ca. 6.5%), quartz (silt-sized, ca. 5.5%), clinopyroxene, epidote, green hornblende, microcline, muscovite, unidentified rock, oolites, no nodules.

21. Splayed-rim Bowl (field no. 28.9.354; Museum no. 29-102-407; PMBS22)
Mineralogy: quartz (silt-sized, ca. 3%), calcite (silt- and sand-sized, ca. 1%), chert, clinopyroxene, green hornblende, muscovite, opaques, igneous rock fragments, no nodules, organic material (ca. 3%).

22. Spinning Bowl (field no. 27.10.901; Museum no. 29-102-488; PMBS24)
Mineralogy: calcite (silt- and sand-sized, ca. 6.5%), quartz (silt-sized, ca. 5.5%), clinopyroxene, opaques, plagioclase, two unidentified rocks and/or fossils, oolites, shell fragments, no nodules.

c. Palestinian and Egyptian-style special object types

23. Female Figurine Plaque (field no. 25.11.544; Museum no. 29-103-885; PMBS52)
Mineralogy: quartz (silt-sized, ca. 0.4%), calcite (silt- and sand-sized, ca. 0.1%), clinopyroxene, green hornblende, tourmaline, unidentified fossil, shell fragments, no nodules.

24. Female Figurine Plaque (field no. 27.10.481; Museum no. 29-103-925; PMBS56)
Mineralogy: calcite (silt- and sand-sized, ca. 9%), quartz (silt-sized, ca. 8%), clinopyrozene, microcline, muscovite, opaques, two unidentified rocks, algal calcite, oolites, rare nodules, organic material (<1%).

25. Female Figurine Plaque (field no. 25.11.308; Museum no. 29-103-933; PMBS32)
Mineralogy: calcite (silt- and sand-sized, ca. 16%), quartz (silt-sized, ca. 14%), biotite, clinopyroxene, epidote, opaques, unidentified rock, no nodules, organic material (<1%).

26. Female Figurine Mold, upper portion (field no. 27.12.2; Museum no. 29-103-940; PMBS14)
Mineralogy: calcite (silt- and sand-sized, ca. 13%), quartz (silt-sized, ca. 12%), epidote, muscovite, plagioclase, tourmaline?, no nodules, organic material (ca. 1%).

27. Female Figurine Mold, lower portion (field no. 27.11.288; Museum no. 29-103-1063; PMBS59)
Mineralogy: quartz (silt-sized, ca. 0.6%), calcite (silt- and sand-sized, ca. 0.4%), basaltic hornblende, clinopyroxene, microcline, muscovite, opaques, unidentified fossil, shell fragments, rare nodules.

28. Anthropomorphic Head (field no. 26.11.56; Museum no. 29-103-950; PMBS37)
Mineralogy: calcite (silt- and sand-sized, ca. 5.5%), quartz (silt-sized, ca. 4.5%), epidote (ca. 1%), clinopyroxene, muscovite, opaques, two algal limestones?, unidentified fossil, shell fragments, nodules (<1%), some organic material.

29. Anthropomorphic Head (field no. 25.11.595; Museum no. 29-103-905; PMBS55)
Mineralogy: calcite (silt- and sand-sized, ca. 3.5%), quartz (silt-sized, ca. 2.5%), chert, clinopyroxene, microcline, muscovite, opaques, tourmaline?, algal limestone, two unidentified fossils, shell fragments, no nodules, organic material (<1%).

30. Anthropomorphic Mask (field no. 27.11.282; Museum no. 29-103-868; PMBS29)
Mineralogy: calcite (silt- and sand-sized, ca. 2.5%), quartz (silt-sized, ca. 1.5%), igneous rock fragments (sand-sized, ca. 0.1%), chert, clinopyroxene, epidote, microcline, opaques, plagioclase,

zircon?, three unidentified rocks and/or fossils, fossiliferous limestone, oolites, shell fragments, nodules (ca. 1%).

31. Duck or Goose Head (field no. 25.11.537; Museum no. 29-103-970; PMBS53)
Mineralogy: quartz (silt-sized, ca. 0.2%), calcite (silt- and sand-sized, ca. 0.1%), clinopyroxene, feldspar, muscovite, opaques, no nodules, organic material (1%).

32. Cobra Figurine (field no. 26.10.515; Museum no. 29-103-1032; PMBS46)
Mineralogy: calcite (silt- to granule-sized, ca. 4.5%), quartz (silt-sized, ca. 3.5%), igneous rock fragments (sand-sized, ca. 0.3%), chert (sand-sized, ca. 0.2%), plagioclase (sand-sized, ca. 0.1%), clinopyroxene, green hornblende, muscovite, opaques, two unidentified rocks and/or fossils, oolites, calcareous microfossils, radiolarian chert, no nodules, organic material (ca. 1%).

33. Cobra Figurine (field no. 27.10.818; Museum no. 29-103-915; PMBS48)
Mineralogy: calcite (silt- and sand-sized, ca. 8.5%), quartz (silt-sized, ca. 7.5%), biotite, clinopyroxene, epidote, opaques, plagioclase, two unidentified fossils, foraminiferal and shell fragments, nodules (ca. 0.5%).

34. Bull Figurine Head (field no. 27.9.383; Museum no. 29-103-994; PMBS58)
Mineralogy: calcite (silt- and sand-sized, ca. 2%), quartz (silt-sized, ca. 1%), nodules (<1%).

35. Feline Figure (field no. 26.9.174; Museum no. 29-103-1019; PMBS1)
Mineralogy: calcite (silt- and sand-sized, ca. 1.25%), quartz (silt-sized, ca. 0.75%), clinopyroxene, epidote?, green hornblende, muscovite, opaques, plagioclase, zircon, two unidentified rocks and/or fossils, oolites, shell frgaments, few nodules, organic material (ca. 1%).

36. Miniature Storage Jar from Probable Donkey Rhyton (field no. 25.11.679; Museum no. 29-103-941; PMBS54)
Mineralogy: calcite (silt- and sand-sized, ca. 4.5%), quartz (silt-sized, ca. 3.5%), clinopyroxide, epidote?, green hornblende, opaques, unidentified fossil, shell fragments, no nodules, organic material (ca. 1%).

37. Zoomorphic Stand (field no. 27.10.795; Museum no. 29-103-864; PMBS19)
Mineralogy: quartz, (silt-sized, ca. 0.4%), calcite (silt- and sand-sized, ca. 0.1%), epidote, muscovite, opaques, unidentified fossil and microfossil material, no nodules, organic material (1-2%).

Table III. (cont'd)

38. Zoomorphic Stand (field no. 27.10.820; Museum no. 29-103-862)
Mineralogy: calcite (silt- and sand-sized, ca. 2.75%), quartz (silt-sized, ca. 2.25%), epidote, muscovite, opaques, plagioclase, trempolite-actinolite, two unidentified rocks and/or fossils, oolites, shell fragments, no nodules.

39. Anthropomorphic Head Applique on Tall Cylindrical Stand (field no. 27.11.14; Museum no. 29-103-858; PMBS49)
Mineralogy: calcite (silt- and sand-sized, ca. 1.75%), quartz (silt-sized, ca. 1.25%), chert, clinopyroxene, muscovite, olivine, opaques, plagioclase, igneous rock fragments, two unidentified rocks and/or fossils, oolites, shell fragments, no nodules.

40. Kernos with Miniature Storage Jar (field no. 27.10.454; Museum no. 29-102-927; PMBS8)
Mineralogy: calcite (silt- and sand-sized, ca. 4.5%), quartz (silt-sized, ca. 3.5%), biotite, epidote?, muscovite, opaques, no nodules.

41. Miniature Bowl (field no. 26.9.182b; Museum no. 29-102-434; PMBS9)
Mineralogy: calcite (silt- and sand-sized, ca. 10.5%), quartz (silt-sized, ca. 7%), chert (ca. 0.4%), clinopyroxene (ca. 0.2%), biotite?, opaques, no nodules, organic material (2-3%).

42. Dumbbell-shaped Object (field no. 27.11.200; Museum no. 29-103-1056; PMBS45)
Mineralogy: calcite (silt- to granule-sized, 5.5%), quartz (silt-sized, ca. 4.5%), clinopyroxene?, muscovite, opaques, plagioclase, nodules (<1%), organic material (<1%).

43. Uncertain Object (field no. 25.11.520; Museum no. 29-103-951; PMBS57)
Mineralogy: quartz (silt-sized, ca. 0.2%), calcite, (silt- and sand-sized, ca. 0.1%), clinopyroxene, epidote?, opaques, unidentified fossil, shell fragments, no nodules, organic material (ca. 3%).

2. *Glazed pottery specimens*

44. Jar (field no. 26.8.72; Museum no. 29-105-507; PMBS43)
Mineralogy: quartz (silt-sized, ca. 0.25%), opaques, no nodules.

45. Bowl (field no. 25.11.225; Museum no. 29-105-526; PMBS44)
Mineralogy: quartz (silt-sized, ca. 1%), opaques, sandstone fragments, nodules (3-4%).

3. *Mycenaean pottery specimens*

46. Amphoroid Krater sherd (field no. 28.12.4; Museum no. P.29-103-412; Level IX; PMBS30)
Mineralogy: quartz (silt-sized, ca. 0.25%), muscovite, no nodules.

47. Probable Globular Stirrup Jar (field no. 27.11.310b; Museum no. 29-103-480; PMBS31)
Mineralogy: quartz (silt-sized, ca. 0.5%), chert, no nodules.

48. Small Juglet handle (field no. 26.8.148; Museum no. 29-103-568; PMBS26)
Mineralogy: quartz (silt-sized, ca. 0.25%), calcite, muscovite, opaques, no nodules.

49. Small Jug (field no. 26.8.128; Museum no. 29-103-571; PMBS28)
Mineralogy: quartz (silt-sized, ca. 0.25%), calcite (silt- and sand-sized), no nodules.

50. Shallow Cup (field no. 26.11.44a-b; Museum no. 29-103-633a; PMBS27)
Mineralogy: quartz (silt-sized, ca. 0.25%), calcite (silt-sized), chert, no nodules.

4. *Cypriot pottery specimens*

51. Base Ring II Bowl (Field no. 27.10.807; Museum no. 29-102-497; PMBS33)
Mineralogy: quartz (silt-sized, ca. 1%), calcite (silt- and sand-sized, ca. 0.1%), nodules (<1%).

52. Base Ring II Juglet handle (field no. 27-9-311; Museum no. 29-103-564; PMBS36)
Mineralogy: calcite (silt- and sand-sized, ca. 0.6%), quartz (silt-sized, ca. 0.4%), opaques, no nodules.

53. Base Ring I Jug (field no. 28.10.356; Museum no. 29-103-91; PMBS39)
Mineralogy: calcite (silt- and sand-sized, ca. 0.6%), quartz (silt- and sand-sized, ca. 0.4%), chert (sand-sized), muscovite, opaques, plagioclase, nodules (ca. 1%), organic material (<1%).

54. Base Ring II Jug handle (field no. 27.11.377; Museum no. 29-103-635; PMBS42)
Mineralogy: quartz (silt- and sand-sized, ca. 1.2%), calcite (silt- and sand-sized, ca. 0.3%), opaques, plagioclase, sandstone fragments, no nodules.

55. White Slip II Milk Bowl (field no. 26.9.104d; Museum no. 27-102-537; PMBS34)
Mineralogy: quartz (silt- and sand-sized, ca. 3.5%), tremolite-actinolite (silt- and sand-sized, ca. 2.2%), plagioclase (sand-sized, ca. 0.2%), epidote, opaques, no nodules.

56. White Slip II Milk Bowl (field no. 27.10.731; Museum no. 29-102-507; PMBS38)
Mineralogy: quartz (silt- and sand-sized, ca. 4%), opaques (ca. 2%), clinopyroxene, opaques, plagioclase, no nodules.

Table III. (cont'd)

57. White Slip II Milk Bowl (field no. 28.9.344b; Museum no. 29-102-525; PMBS40)
Mineralogy: quartz (silt- and sand-sized, ca. 4.8%), tremolite-actinolite (sand-sized, ca. 4.7%), igneous rock fragments (ca. 0.2%), chert (ca. 0.1%), clinopyroxene (ca. 0.1%), basaltic hornblende, opaques, plagioclase, nodules (ca. 10%).

58. White Slip II Milk Bowl handle (field no. 27.11.411; Museum no. 29-102-535; PMBS41)
Mineralogy: tremolite-actinolie (silt- and sand-sized, ca. 2.25%), quartz (silt- and sand-sized, ca. 1.75%), plagioclase (ca. 0.2%), calcite (ca. 0.1%), opaques, igneous rock fragments, no nodules.

59. White Slip II Milk Bowl fragment (field no. 27.9.395; Museum no. 29-102-519)
Mineralogy: feldspathic (granitic?) rock fragments (sand-sized, ca. 3.25%), quartz (silt-sized, ca. 2.75%), calcite, nodules (<1%).

60. White Shaved Juglet (field no. 27.10.604; Museum no. 29-102-772; PMBS35)
Mineralogy: not analyzed.

Inferences about the proveniences of the Beth Shan specimens are based on a comparison of their compositions with those of approximately 4000 Old World samples in the Brookhaven data bank. Two multipvariate computer programs are employed: XSEARCH and XADSEARCH.

XSEARCH searches the data base for samples with compositions similar to those of the Beth Shan specimens. "Similarity" is defined as a mean Euclidean distance in multidimensional space that is equal to or less than any operator-specified distance, based on any combination of chemical elements. After searching, the program generates a list of similar samples, with their mean Euclidean distances from the Beth Shan specimens, and the "best relative fit" distances. The latter distance is the mean Euclidean distance remaining between two specimens after the concentrations of elements in the searched-out specimen have all been multiplied by a common factor that produces the minimum distance. The rationale for this operation is that, if a neutral diluent such as clean sand temper, or simply moisture, is present in one specium more than in another, then evidence of their relationship will be provided by the smaller "best relative fit" distance, even though they may be separated by a substantial mean Euclidean distance.

Rather than comparing individual samples, XADSEARCH begins with a group of specimens which are hypothesized to be related chemically. The goal is to find other samples in the data bank that could belong to this group, taking into account all the multiple correlations among the group analytical data. A particular set of operator-specified chemical elements is chosen, which is standardized by the logarithms of the concentrations, and the program calculates

the variance-covariance matrix of the group and its inverse. A new set of standardized orthogonal coordinates, equal to the number of elemental coordinates originally specified, is generated by linear combinations of the latter. The orthogonal coordinates are the eigenvectors of the variance-covariance matrix, and the sum of the squares of the coordinate values of a specimen equals the Mahalanobis distance of that specimen from the centroid of the group. The Mahalanobis distance, in turn, can be directly related to the probability of group membership of a specific specimen, assuming a multivariate normal distribution.

In searching the Brookhaven data bank by XSEARCH, 31 Beth Shan specimens, all belonging to the presumed local group, lacked "matches" and were similar only to one another, at a mean Euclidean distance of 0.10 (Table II). XADSEARCH confirmed the integrity of this group in which certain elements (specifically, lanthanum, scandium, cerium, europium, thorium, chromium, and samarium) were highly correlated. Peripheral specimens, PMBS17 (no. 14) and PMBS20 (no. 13), were calculated to have 58.8% and 65.1% probabilities of belonging to the main group, at a mean Euclidean distance of 0.10. Given the large number of Palestinian and other Near Eastern samples in the Brookhaven data bank, the absence of "matches" for the presumed local group is difficult to understand unless these specimens are indeed of local origin. The eastern Jezreel area of Palestine is poorly represented in the data base, and its geomorphological setting is different from that of the southern Hill Country and central Transjordan, which are better represented. Analyses of local clays from the Beth Shan area are needed to corroborate the proposed local origin of this group.

Nine specimens in the presumed local group match samples from other Palestinian sites (Table II). Three of the specimens (PMBS7, PMBS12, and PMBS23; nos. 6, 11, and 7) are similar to each other, and to samples from the southern coastal area and the Shephelah. Another specimen (PMBS49; no. 39) matches a specimen (PMBS29; no. 30) in the main local grouping, in addition to southern Palestinian samples. Of the remaining three specimens, each had a single match from various parts of the country.

The nine specimens include all but one of the specimens in a small grouping on the dendrogram (above), a related outlier (PMBS16; no. 5), and four peripheral specimens (PMBS49, PMBS9, PMBS22, and PMBS13; nos. 39, 41, 21, and 12) of the main grouping. Either these specimens were imported to Beth Shan from elsewhere in Palestine or the Palestinian "matches" represent exports from Beth Shan. On the basis of the petrographic data (below), it can be proposed that these specimens are of local origin, although containing relatively higher amounts of igneous inclusions; possibly, the latter inclusions account for their chemical divergence from the main local group. A petrographic analysis of the Palestinian "matches" would be of value in evaluating this hypothesis.

On stylistic and other technological grounds, it seems unlikely that these specimens were imported. Why should one cobra stand (PMBS46; no. 32) be imported, and another (PMBS48), which is

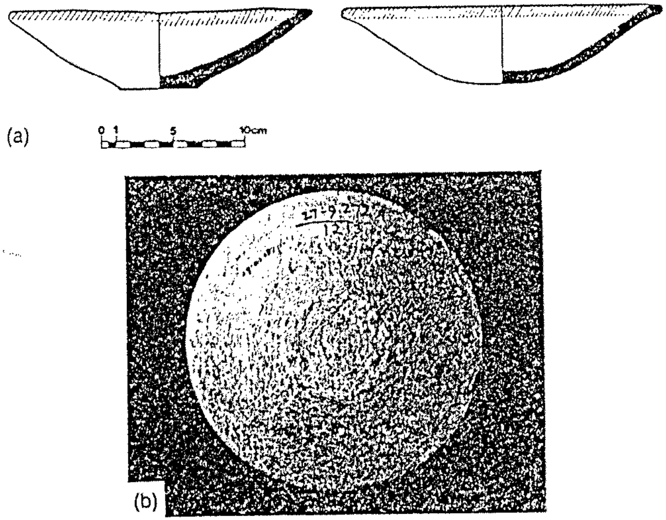

Fig. 6. (*a*) Two Egyptian-style bowls: field no. 27.9.291, University Museum no. 29-102-382 (left); field no. 27.9.271, University Museum no. 29-102-380 (right). (*b*) Exterior view of base of Egyptian-style bowl (field no. 27.9.272a; University Museum no. 29-102-387, diameter 20 cm, height 5.9 cm) showing the tightly packed grooves that resulted from the trimming operation in which numerous inclusions were caught up and dragged by the potter's tool while the vessel rotated.

stylistically and structurally identical, be made locally? Of three splayed-rim bowls (PMBS05, PMBS06, and PMBS22; nos. 18-20; Fig. 6), which display the same stylistic features (e.g., a red-painted band on the rim) and fabrication details (e.g., roughly trimmed bases), why should only one (PMBS22; no. 21) be imported? Comparable artifacts were not tested for the other forms and types, but all represent well-established classes at Beth Shan. There is no inherent reason why they should have been imported, with the possible exception of the storage jars (PMBS12 and PMBS13; nos. 11 and 12).

The inhabitants of the site certainly were not adverse to importing pottery, since Mycenaean and Cypriot vessels were quite common in Levels VII and VIII. Egyptians also might have transported goods, not available in Palestine, from Egypt in native pottery containers, or have imported special pottery objects (such as cultic vessels) from Egypt. The available evidence, however, suggests that few if any of the Egyptian-style pottery artifacts at Beth Shan were produced

abroad; rather, Egyptians chose to have vessels and objects of Egyptian types manufactured at the site.

Petrography[25]*:* The Egyptian-style and Palestinian specimens are also very similar petrographically (Table III),‡ and most likely derive from fluvial or lacustrine clays of recent origin in the Beth Shan region. Calcite inclusions, which fall into the silt-and sand-sized range (0.039-2.00 mm.), generally exceed the number of quartz inclusions, which are silt-sized (0.039-0.062 mm.). Grains of both minerals are well-rounded and normally distributed in a unimodal fashion. On average, the following volumetric amounts of calcite and quartz were recorded for the three subgroups: 4.52% calcite and 3.12% quartz (Palestinian vessel subgroup), 3.58% calcite, 3.68% quartz (Egyptian-style vessel subgroup), and 4.57% calcite, 3.76% quartz (Palestinian and Egyptian-style special object subgroup).

Quartz generally exceeds calcite when the amounts of both are low (<0.5%), but this is possibly a result of the difficulty of detecting calcite which has been heat-altered. A refiring study of Jordanian clays[26] demonstrated that calcite can become cryptocrystalline and cloudy by 600°C, well below the temperature (894.4°C) at which pure calcite breaks down.[27] Some allowance must be made for the complex behavior of calcite in a clay matrix.[28,29] At temperatures above 600°C, the original amount of calcite can often be only approximated by noting reaction rims around voids (resulting from the disintegration of primary calcite) and correcting for any cryptocrystalline calcite which is present.

The presence of accessory minerals in the three presumed local groups is also quite consistent. In order of abundance, nine major accessories are present in each group as follows (the number of specimens containing the mineral is cited in parentheses):

Palestinian vessels: clinopyroxene (11), plagioclase (11), epidote (6), muscovite (5), chert (3), biotite (2), microcline (2), green hornblende (2), and brown hornblende (2).

Egyptian-style vessels: clinopyroxene (4), epidote (3), plagioclase (2), chert (2), microcline (2), green hornblende (2), biotite (1), and muscovite (1).

Palestinian and Egyptian special object types: clinopyroxene (15), muscovite (13), epidote (7), plagioclase (8), chert (5), green hornblende (4), microcline (4), biotite (3), and brown hornblende (1).

‡Petrographic data for all except one of the 60 specimens (no. 60) is provided in Table III. Examination of thin-sections by standard petrographic microscopy enabled the determination of the following characters: (1) the percentage content of minerals exceeding 0.1% by volume; (2) the size range distribution of inclusions exceeding 1% by volume on the basis of 100 randomly selected grains and by optically comparing the inclusion density of the specimen with a series of standard density charts; (3) the presence of other minerals and inclusions (shell fragments, fossils, and organics); (4) grain angularity; and (5) the general ware features, including isolated nodules of clay, which differed in color and composition from the bulk fabric.

Shells, fossils, oolites, foraminiferal remains, opaques, and rock fragments (including igneous, algal and fossiliferous calcareous minerals, as well as radiolarian chert) are common in the three groups. Rare mineral species, which were primarily igneous in origin, included feldspar, olivine, possibly tourmaline, tremolite-actinolite, and zircon. One Palestinian form, a storage jar (no. 11), possibly contains aegerine-augite, cassiterite, and hypersthene; apatite and clinozoisite may be present in a double pilgrim's flask (no. 15). A bull figurine head (no. 34) was exceptional in lacking accessory minerals.

Organic materials, which are visible as elongated burnt-out voids (probably straw) in thin-section, are most prevalent in the special object group. Twelve out of 21 special objects (57%) contain organics, as contrasted with only 5 out of 18 Palestinian vessel specimens (29%) and none of the Egyptian-style vessel specimens. When present, the average amount of organics in the special object specimens is 1.33%, which is comparable to 1.2% in the Palestinian vessel specimens. These averages are on the low side, since voids due to burnt-out organics could not always be distinguished from other types of voids.

The unimodal size distributions of the calcite and quartz grains, as well as the similar suites of accessory minerals, shells, and fossils, in the presumed local assemblages imply that their ware inclusions were derived from the clay rather than having been added as temper. Variations in the amounts of inclusions could result from differential levigation or selected areas of the clay bed, with differing amounts of inclusions, being worked out over time. Clay deposits from the Beth Shan area have not yet been examined in detail, but the combination of igneous and sedimentary rocks, fossils, and shells in the LB Beth Shan wares fits with the immediate geomorphology of the Beth Shan area[30] and suggests a recent fluvial or lacustrine clay deposit was used to make the presumed local pottery and special objects.

The elevated level of organics in some of the special object and Palestinian vessel specimens implies that this material was used selectively as a temper or for some other purpose. For example, organics might have served as emulsifiers in making a more plastic clay that could be manipulated more easily (e.g., in mold-making female figurine plaque nos. 24 and 25), or have provided structural support in fabricating larger, hand-made forms (e.g., nos. 32, 37, 42, and 43). Within the special object group, however, examples of the same type may or may not contain organics (cf. nos. 23–24, nos. 32–33, nos. 37–38, and nos. 40–41). Consequently, beyond suggesting that organics might well have been intentionally added as temper (in order to prevent cracking of the ware upon firing) and for special fabrication purposes, no single pattern of usage is supported by the data.

Between a quarter and a half of the presumed local specimens contained clay nodules, which are discrete from the main clay body. On average, they constitute less than 1% of the total ware volume, although nodules account for as much as 2–3% in one specimen (no. 7). A glazed pottery specimen (no. 45) contains 3–4%, and of three Cypriot specimens with nodules, the structures comprise approximately 10% of the fabric of one White Slip II specimen (no. 57). The nodules are usually the same color as the ware, but are occasionally more gray or more red. Their inclusional content differs little from that of the bulk fabric, and their rounded shapes are unlike that of a grog temper. They probably were not the result of an oxidative firing effect, since nodules did not form in a similar clay body from Transjordan which was refired in an oxidizing atmosphere.[26] Possibly, the nodules represent a second clay that was mixed with the main clay body to improve the latter.

Original Firing Temperature[23]*:* Presumed local specimens from the three stylistic groups (Palestinian vessels, Egyptian-style vessels, and special objects) were also examined with an SEM to establish (1) the extent of the glassy phase (vitrification), which relates to the temperature and duration of the original firing; (2) the presence or absence of surface decoration, such as a slip or glaze; and (3) the general physical and chemical characteristics of the surface layer (when present) as compared to the bulk fabric. A range of vessel and object types were included in the study, in order to assess the importance of this variable.

Almost all the presumed local specimens exhibit either no clay particle sintering or are at an initial stage of vitrification.[§] One type (dumbbell-shaped object no. 42) was made from unfired clay. No change in the vitrification structure was noted for these specimens when they were refired between 500 and 700°C; above 800°C, the wares began to bloat and crack on the surface, leading to total disintegration by 900°C. A white surface efflorescence also appeared on pieces refired above 700°C. Several specimens (viz., storage jar nos. 10–12; juglet no. 6; krater no. 3; and ring stand no. 18) originally had an intermediate vitrification structure. A series of microscopic structural changes occurred in the latter specimens upon refiring between 800 and 1000°C, which was accompanied by some surface

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§The ancient firing-temperature range for each ware type was determined as follows. The original degree of vitrification of clay particles in an ancient specimen was compared with that of small pieces cut from that vessel and others of the same ware type, which had been refired to specific temperatures (500, 600, 700, 800, 900, or 1000°C). The pieces were cut with a nondeformational diamond saw perpendicularly to the artifact's surface; thin-sections and SEM samples were similarly prepared. Each piece was refired to a specific temperature in a servo-controlled muffle furnace for eight hours in an oxidizing atmosphere. The vitrification structures of the original and refired samples were then examined by SEM and defined. According to the terminological distinctions in the literature (Ref. 31), an initial vitrification structure shows minimal fusion between clay particles, whereas large fused areas are characteristic of an extensive vitrification structure. The color changes of the wares and surface layers when refired can also be of value in qualitatively assessing the original temperatures and environments of the firings.

cracking and a white efflorescence. The intermediate structure remained relatively stable up to 800°C. Above this temperature, fine bloating holes (several microns in diameter) began to appear in a continuously fused fabric. The holes increased in size up to 1000°C.

The presumed local wares are highly calcareous (Table I), with weight percentages of the oxide ranging between 6.2% and 44.8%. Previous studies of Jordanian and Near Eastern calcareous wares[26,31] have established that the initial stage of vitrification of a calcareous ware begins around 700°C, an intermediate structure consolidates by 750°C, and extensive vitrification with bloating holes appears around 950°C. On this basis, the original firing temperatures of the majority of the Level VII-VIII specimens can be estimated as 500–700°C. The small group of specimens with original intermediate vitrification structures were probably fired to around 800°C. Greater precision in estimating the original firing temperature range is dependent on a fuller knowledge of several interacting variables—the highest temperature attained, the period of time at various temperatures, and the relative exposure period of time of the pottery to oxidizing and reducing conditions.

An upper temperature limit for the presumed local wares could be defined by the bloating and surface cracking that began to occur on all the refired specimens at about 800°C. The fact that the pottery was generally fired well below this temperature indicates that the potters were probably aware of the limitations of their materials.

A lower temperature limit could be inferred from the petrographic analysis. Green hornblende occurs in two Palestinian vessel forms (folded bowl no. 2, and jar no. 9), an Egyptian-style vessel form (splayed-rim bowl nos. 20 and 21), and four special object types (female figurine plaque no. 23, cobra figurine no. 32, feline figure no. 35, and miniature storage jar no. 36). Brown or basaltic hornblende was recorded in two Palestinian forms (storage jar no. 10 and pilgrim's flask no. 14) and one special object type (female figurine mold no. 27). Green hornblende is transformed to brown hornblende around 750°C,[32,33] but the mineralogical change can occur at a lower temperature (550°C) in a clay matrix.[26] Although the brown hornblende might have entered the ware as a separate addition or via the clay, it is more likely that it underwent transformation during firing. Its presence then in three of the Beth Shan specimens would suggest that firing temperatures generally exceeded 550°C. The transformation of calcite from a macrocrystalline, translucent variety at 550°C to a cryptocrystalline, cloudy form at 600°C[26] further supports this conclusion, since the calcite in the all the Level VII-VIII specimens is of the latter variety.

Color changes also provide an approximate measure of the original firing temperature range. Thus, the predominant colors of the exterior subsurfaces of presumed local wares vary between light red (2.5YR 6/6) and reddish brown (5YR 7/6), with an occasional pink (5YR 7/4) and very pale brown (10YR 7/2). The unrefired clay of no. 42 is reddish brown (5YR 7/6). Comparison with the refired specimens indicates that these colors were stable up until 700°C, above which reddish hues lightened to a pink (5YR 7/4) or reddish

yellow (5-7.5YR 7/6); the very pale brown also became a pink (5YR 7/4). A somewhat redder hue (5YR 7/6) had reappeared by 1000°C. The original ware colors of the Beth Shan pottery accords with the results from the SEM refiring study, viz., most of the pottery was fired between 500 and 700°C, and a small number of specimens were heated to a slightly more elevated temperature (ca. 800°C).

The thickness of a dark core, representing unoxidized elemental carbon, is a measure of the amount of organic matter in the clay, whether added separately or combined with the clay originally, and of the original firing temperature (organics begin to burn out at around 450°C). The majority of the Beth Shan pottery are designated as having thick cores (greater than 75% of the vessel wall thickness). Since the amount of organics added to the clay body was not exceptionally great, the pottery apparently was not fired to a very high temperature or the firing was of short duration. A kiln or bonfire might have been used to fire the Beth Shan pottery, but since no firing installations were discovered at the site, this issue cannot be resolved.

Fabrication: Egyptian-style bowls (Fig. 6), which are characterized by horizontal red painted bands on the interior of a splayed rim, demonstrate especially well the extent to which Egyptian pottery techniques were employed in Beth Shan workshops. Their roughly trimmed exteriors, extending from the base up to the middle sidewall, are identical to their counterparts made in Egypt (as based on a preliminary examination of New Kingdom pottery in the University Museum collection, and on personal communication from Dorothea Arnold). The pottery style could have been adopted by a Palestinian potter who imitated an imported Egyptian vessel, but, when the particular style is achieved using the same techniques, then it becomes almost a certainty that some potters from Egypt were at Beth Shan, whether actively engaged in the manufacture of pottery themselves or in instructing Palestinian potters on how to achieve the style using specific Egyptian techniques. In either case, locally available materials were used to replicate an Egyptian pottery form according to traditional Egyptian practice.

Summary: Egyptian technological influence is evident throughout the manufacturing process of both Egyptian-style and Palestinian pottery artifacts. In addition to the same local clay being used, the wares of Level VII/VIII Palestinian artifact types are very comparable to those of the Egyptian-style artifacts in terms of (a) their volumetric amounts of inclusions (average of 7.2% and 6.5% of calcite and quartz particles, respectively, and about 1.3% of organics when present), and (b) their original firing temperature range (500–700°C).

Earlier LB Palestinian wares have lower volumetric quantities of inclusions and were higher fired, e.g., LB I Baq'ah Valley (Jordan) pottery contained an average of 5.1% quartz and calcite inclusions, with minimal organics, and were fired in the 700–850°C range.[26]

According to preliminary observations, contemporaneous wares from Level IX at Beth Shan also contain less inclusions and were higher fired. Since more heavily tempered, lower fired wares are characteristic of Egyptian New Kingdom pottery made from Nile alluvial clays (Dorothea Arnold, personal communication), it can be plausibly argued that the Beth Shan clays were prepared and fired in customary Egyptian fashion. Indeed, compared to other locales in Palestine, Beth Shan most nearly duplicated the conditions of an Egyptian town in the Delta, with its hot climate and proximity to a major river, into which a network of waterways flowed and were periodically flooded. Other factors might have contributed to a decline in potting standards—mass production, depletion of pure clay beds, and decreased water supplies needed for levigation[20]—but its specific expression at Beth Shan, correlating with the contemporaneous Egyptian industry, implies that the Egyptians controlled the Beth Shan pottery industry at its most basic level, i.e., material supply and processing.

Egyptian technological influence is also apparent at the formation and surface finishing stages of manufacture. For example, bases on Beth Shan Palestinian vessels, which had hitherto been well trimmed, now were often poorly finished, like the Egyptian-style bowls from the site.

Silicate Artifacts[1]

The impact of Egyptian technological traditions can also be seen in the silicate industry of 13th c. B.C. Beth Shan. A very large hoard of glass and faience jewelry and vessels (Figs. 7 and 8), buried below or in the vicinity of the stairway, constitutes the largest collection of silicate artifacts from LB Palestine—more than 1500 beads, 300 pendants, and 40 vessels. Some of these objects probably played a direct role in the cult. Faience lotus chalices, which were very common in the Beth Shan group, were used to present food offerings to theriomorphic deities in New Kingdom Egypt. The masses of beads and pendants had most likely been strung together originally to form pectorals or collars that adorned temple personnel or a cult statue. Many of the pendant types were Egyptian-style types, representing Egyptian deities (e.g., Bes and the baboon of Thoth) and/or hypostatized concepts (life [*ʿankh*], stability [*ḏd*], etc.). These pendants had apparently been mixed together indiscriminately on the same jewelry piece with Palestinian types (the star disc, crescent with

[1]All the silicate materials were initially examined macroscopically and under low-power magnification (up to × 180), using a stereozoom scope with fiber optic lighting. At this level of analysis, the various materials (glass, frit, and faience) could be characterized preliminarily, fabrication techniques defined, larger inclusions noted, and the extent of weathering assessed. A definitive characterization of the materials, including their vitrification structures and inclusions, was then carried out using an SEM with an attached energy dispersive system (EDS) for semi-quantitative chemical determination. Both original surfaces and prepared cross-sections were examined.

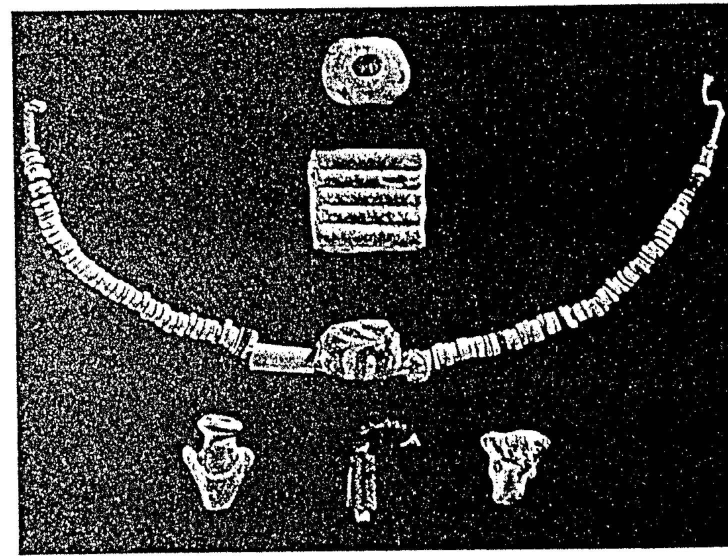

Fig. 7. Representative examples of beads and pendants, including several from the hoard under the Level VII temple stairway. At the bottom, from left to right, are shown an Egyptian *ib* ("heart") pendant (decorated with lead antimonate yellow and calcium antimonate white glass; field no. 25.11.343; University Museum no. 29-105-744), a pendant possibly depicting reeds (of standard Egyptian faience, overlaid by a cobalt blue glaze; field no. 25.11.475; University Museum no. 29-104-311), and a ram's head pendant, most likely of Syro-Palestinian inspiration (with horns comprised of spiralling rods of manganese-iron brown and calcium antimonate white, and eyes defined by impressed crumbs of the same colored glasses; field no. 25.11.394; University Museum no. 29-104-192). In the middle of the string of beads (mostly discs, cylinders, and fluted varieties of standard Egyptian faience) is a large barrel-shaped bead (field no. 26.9.112e, University Museum no. 29-104-433) with a feather or ogee pattern of calcium antimonate white glass overlaid on a base glass uniquely colored with fine silver particles in suspension. Above a multi-tubular bead spacer (field no. 27.10.38, University Museum no. 29-104-359), used to separate strands of beads and pendants on large necklaces or collars, is an eye bead (field no. 28.11.382, University Museum no. 29-104-503), which was made by pressing manganese-iron brown and calcium antimonate white crumbs one on top of the other into a cupric blue-green glass surface. (Photograph: P. McGovern.)

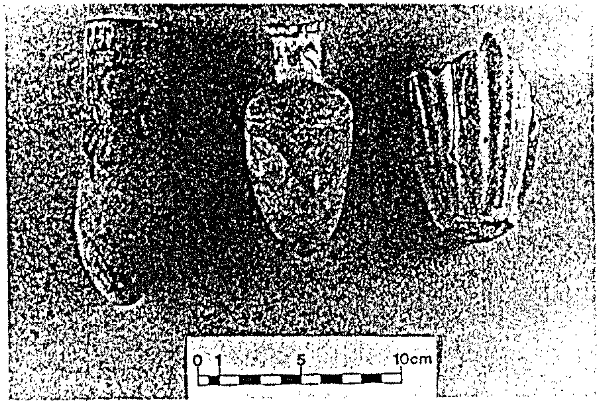

Fig. 8. Three Egyptian-style vessels from the Level VII/VIII temple precinct: (*a*) a jar (field no. 28.8.123, University Museum no. 29-105-500) with a lotus and lily pad motif (of standard Egyptian blue-green glazed faience, decorated with manganese-iron brown glaze), (*b*) an amphoriskos (field no. 26.8.101a, University Museum no. 29-105-667) with a feather/ogee design and toroid rim (of calcium antimonate white glass, decorated with lead antimonate yellow glass), and (*c*) a fluted lotus chalice fragment (field no. 26.9.116, University Museum no. 29-105-504), of standard Egyptian blue-green glazed faience, with petals delineated by overlaid lead antimonate yellow and cobalt blue glazes). Examples *a* to *c* are ordered from left to right. (Photograph: P. McGovern.)

horns, etc.), which were symbolic of Canaanite deities and religious ideas.[34]

The glass industry originated in the region of Syria-Palestine toward the end of the Middle Bronze Age (MBA) around 1600 B.C., and it is likely that a local variant of the industry existed at Beth Shan prior to Level VIII. The glasses and frits were of the standard MB-LB types.[35] Specimens are well-fused, and in the case of frits, which are pre-fused silicate materials incorporated into a glaze/glass mixture or used separately,[36,37] individual crystals can be seen embedded in an extensively vitrified matrix. The surface particles of the refired frit sometimes had fused to form a glaze. The particle sizes for the variously colored frits (50–100 mμ in diameter) and the relative fraction of glass were comparable to examples from Nuzi[37]) and in New Kingdom Egyptian Blue specimens.[38] Despite their physical similarities, frits and glasses, however, were less common in Levels VII and VIII at Beth Shan than other LB Syro-Palestinian sites.[35]

After the site was converted into an Egyptian military garrison, faience of standard New Kingdom type, which was lower fired than Syro-Palestinian faiences, became prevalent; concurrently, the relative percentage of frit and glass declined. Of those specimens studied, the

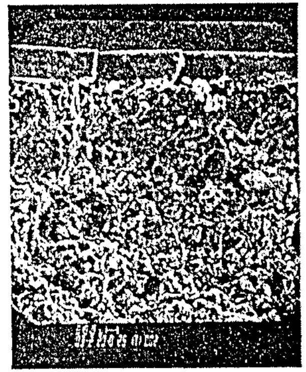

Fig. 9. SEM micrograph at × 500 of a lead antimonate yellow overglaze on a standard Egyptian blue-green glazed faience (petal or leaf pendant, field no. 26.9.171, University Museum no. 29-104-334). The yellow glaze is clearly distinct from an underlying glassy layer, which was formed by salts and copper ion migrating to the surface upon drying (efflorescence), and the poorly vitrified interior silica particles. (Photograph: P. McGovern.)

faience had been made by the efflorescence technique[39] in which salts and other ions migrated to the surface during the drying process and were then fired to a glaze.[40] The diffuse glaze boundaries and very little sintering of interior silica particles of the Beth Shan examples suggest that the drying process was not very intensive and/or that the firing temperature range was relatively low. Only cupric blue-green and hematite red glazed faience were effloresced. Other colors (yellow, white, gray, etc.), which were first developed within the Syro-Palestinian glass/frit industry, were overlaid as glazes (up to 300 mμ thick) onto the effloresced surfaces, probably as liquid slurries, and fired (Fig. 9).

A more detailed chemical analysis of the silicate glazes and glasses by PIXE** revealed other significant details about their composition and place of manufacture.

Sodium appears to have been the primary flux in the small object specimens (Table IV; the chemical data is published as Table 3 in Ref.

**Before PIXE analysis, surfaces were ground down as much as a tenth of a millimeter with an alumina burr, to minimize surface weathering effects. The PIXE system is well-suited to such an investigation; the beam can be reduced to 0.5 mm, which is quite adequate for a material whose homogeneity has been checked independently (for experimental details, see Ref. 41). As many as twenty-five elements were typically measured, and the weight percentages (expressed as the oxides) were then normalized to a hundred percent.

Table IV. Analytical corpus of Beth Shan silicate small objects

Color Reference	Field No.	Locus	Description
YELLOW1 WHITE1	25.11.343	1086, Level VII	*ib* ("heart") pendant (Ref. 24: no. 256). White glass with yellow and white impressed latitudinal bands.
BROWN1 BLUE1 WHITE2	25.11.393	Below Steps of 1068 Level VIII	Ram's head pendant (Ref. 24: no. 87). White glass with brown overlay; dark brown impressed helices on horns; brown and white impressed circular crumbs for eyes; blue nostrils; red beneath horns not visible.
WHITE3 WHITE4 BROWN2 SILVER1	25.11.394	1086, Level VII	Ram's head pendant (Ref. 24: no. 89). White glass with horns added as white and brown canes; impressed silvery open circles and brown circular crumbs define eyes; piece of malachite inserted into middle of left eye; silvery impressed crumbs on nostrils.
YELLOW2 PURPLE1	25.11.423	North of Steps of 1068, Level VII	Small mandrake fruit pendant (Ref. 24: no. 169). Yellow frit with purple glaze overlay.
BROWN3 BROWN4	25.11.441	1062, Level VII	Collared spheroid bead. Brown and white swirled glass.
BLUE2	25.11.454	1068, Level VII	Barrel bead. Blue glass.
WHITE5 BROWN5 BL/GR1 SILVER2 BLACK1	25.11.461	1068, Level VII	Barrel bead. Silvery glass with brown, blue-green, and white impressed crumbs; black interior matrix.
WHITE6 WHITE7	25.11.462i	1068, Level VII	Barrel bead. White glass with purple impressed bands in feather or ogee pattern.
WHITE8 PURPLE2	25.11.462ii	1068, Level VII	Barrel bead. White glass with purple impressed bands.
WHITE9 PURPLE3	25.11.462iii	1068, Level VII	Barrel bead. White glass with purple impressed bands.
BLUE3	25.11.475	Near Steps of 1068, Level VII	Reeds(?) pendant (Ref. 24: no. 216). Blue glazed faience. Two cylindrical beads joined to blue-green suspension rings on each end.
BL/GR2 BL/GR3	25.11.486	Near Steps of 1068, Level VII	*dd* pendant (Ref. 24: no. 223). Blue-green glazed faience.
SILVER3 SILVER4 WHITE10	26.9.112e	1105, Level VII	Barrel bead. Silvery glass with white impressed bands in feather or ogee pattern.
BLUE4	26.9.154a	1062, Level VII	Oblate/spheroid bead. Blue transparent glass.
GRAY1 YELLOW3	26.9.171	Below southern wall of 1062 Level VIII	Petal or leaf pendant (Ref. 24: no. 210). White faience with yellow and gray overlays.

Table IV. (cont'd)

Color Reference	Field No.	Locus	Description
BLUE5	27.9.451	1213A, Level VII	Hexagonal ellipsoid bead. Egyptian Blue frit.
BLUE6	27.9.472a	1221, Level VIII	Fluted oblate/spheroid bead. Egyptian Blue frit.
RED1	27.9.472c	1221, Level VIII	Disc bead. Red glazed faience.
GR-IX2	27.10.39	1232, Level IX	Oblate/spheroid bead. Transparent green glass.
BLU-IX7	27.10.131	1232, Level IX	Cylindrical bead. Blue glass.
BLA-IX-2 WHI-IX11	27.10.369	1236, Level IX	Barrel bead. Black glass with white impressed band.
BLU-IX8	27.10.435	1242, Level IX	Cylindrical bead. Blue glass.
BL/GR4	27.11.159a	1284, Level VII	Petal or leaf pendant (Ref. 24: no. 201).
RED-IX2	28.8.50	1334, Level IX	Disc bead. Red glazed faience.
BLU-IX9	28.10.424c	1241, Level IX	Lenticular cylinder bead. Egyptian Blue frit.
B/GR-IX5	28.10.465c	1396, Level IX	Cylindrical bead. Blue-green glazed faience.
BLU-IX10	28.11.174b	1398, Level IX	Barrel bead. Blue glass.
WHITE12 GRAY3 BROWN6	28.11.257	1399, Level VIII	Oblate/spheroid bead. Gray glass with brown and white impressed crumbs.
BLA-IX3 B/GR-IX6 BRO-IX7 WHI-IX13	28.11.369	1331, Level IX	Cylindrical bead. Gray glass with white, green, and brown impressed crumbs.

43), since five specimens contain between seven and ten percent of the oxide. The majority of the specimens, however, have much lower sodium values, which was most likely the result of leaching; otherwise, temperatures as high as 1723°C (the melting point of pure silica), presumably beyond the pyrotechnological expertise of the period, would have been required to vitrify the silica.

Low potassium values for most of the specimens probably also reflect leaching effects; the Beth Shan small objects overall averaged about 2.8% potassium oxide. Several Beth Shan objects (PURPLE1; BLA-IX2; GRAY3), however, retained as much as six to seven percent of potassium, suggesting that a plant material was used in conjunction with a sodium salt as a flux.

Table V. Analytical corpus of Beth Shan silicate vessels

Color Reference	Field No.	Locus	Description
YELLOW4 BLACK4	26.8.98	Below Floor of 1068, Level VIII	Yellow, white, and black decoration on mottle white base glass.
WHITE14	26.8.101b	Below Floor of 1068, Level VIII	Rim and neck of pomegranate vessel with six sepals. Yellow sepal tips on white base glass.
YELLOW5 WHITE15	26.8.47	Below Floor of 1068, Level VIII	Flask fragment. Yellow and white decoration on white base glass.
WHITE16 YELLOW6 GRAY4	25.11.415	Below Floor of 1068, Level VIII	Flask. Yellow decoration (body, neck, and rim) on white glass. Vertical strands of yellow, gray, and white on handles. Gray and white toroid rim.
BROWN8 BLUE11	26.9.116	1105, Level VII	Jar or jug. Blue-green glazed faience with yellow and blue overlays on exterior.
BROWN9 BL/GR7	26.8.102b	Below Floor of 1068, Level VIII	Bowl. Blue-green glazed faience, with dark brown decoration.
BLACK5 BL/GR8	27.10.834b	1264, Level VII	Bowl. Blue-green faience, with black decoration.
BL/GR9	26.8.72	Below Floor of 1068, Level VIII	Jug or jar. Blue-green glazed pottery (exterior).
BL/GR10	27.11.2	1267, Level VII	Bowl. Blue-green glazed pottery.
BLUE12	27.10.789	1262, Level VII	Egyptian Blue frit cake.

The mean contents of sodium (0.23%) and potassium (0.30%) in the vessel glasses and glazes (Tables V and VI) were less than a quarter of the values for the small objects. The amounts of alkaline earths and aluminum of the vessels were also half those of the small objects, which contained about 4% aluminum and calcium, and 1.5% magnesium, in accord with other published results.[44,45] The vessels would then appear to have been more subject to weathering, even though they were found in the same archaeological contexts as the beads and pendants.

Heavy metal colorants were even more distinctive of the two collections (viz., small objects and vessels). Computer clustering of the PIXE data for titanium and elements of higher atomic number, which includes the colorants and associated minor and trace elements, revealed very distinct groupings of similar looking colors of vessels and small objects on a dendrogram (Fig. 10).

The dendrogram was generated by a hierarchical aggregative algorithm in the Numerical Taxonomic System, NTSYS.[46] Employing the unweighted pair-group method, the two examples, which were separated by the smallest Euclidean distance in multidimensional hyperspace were first merged, the centroid of these two examples calculated, the next closest sample merged, and so forth. The oxide data were expressed in logarithms, since many chemical elements appear to be lognormally distributed in nature, and relative rather

Table VI. PIXE analyses of Beth Shan silicate vessels and Egyptian Blue Frit Cake

Color Reference Vessels	Na_2O	MgO	Al_2O_3	SiO_2	S	Cl	K_2O	CaO	TiO_2	Cr_2O_3	MnO
YELLOW4	0.000	0.520	1.10	80.1	4.33	0.343	0.749	5.90	0.069	0.174	0.109
BLACK4	0.000	0.478	2.35	59.9	14.5	0.534	2.63	14.7	0.165	0.190	2.41
WHITE14	0.000	0.405	1.99	92.5	1.30	0.118	2.12	0.729	0.114	0.019	0.020
YELLOW5	0.000	0.396	2.07	72.4	8.99	0.182	1.86	5.75	0.102	0.070	0.018
WHITE15	0.000	0.893	3.08	83.1	5.04	0.198	2.12	4.42	0.136	0.043	0.027
WHITE16	0.000	0.779	2.01	89.1	2.86	0.277	1.37	2.44	0.059	0.024	0.014
YELLOW6	0.000	0.943	1.19	88.3	3.75	0.281	0.768	2.50	0.050	0.032	0.0045
GRAY4	0.000	0.419	1.79	90.9	3.04	0.129	1.37	1.93	0.034	0.023	0.0099
BROWN8	1.74	1.01	0.705	56.9	5.00	0.612	1.24	5.00	0.071	0.057	0.014
BLUE11	0.000	1.15	0.836	85.5	4.92	0.497	0.911	4.11	0.035	0.051	0.027
BROWN9	0.000	0.251	1.60	92.6	0.242	0.186	0.691	1.25	0.044	0.013	0.852
BL/GR7	0.000	0.408	0.700	95.1	0.280	0.436	0.515	0.663	0.039	0.015	0.012
BLACK5	1.18	0.294	1.56	75.2	4.73	0.287	2.07	3.86	0.075	0.044	5.25
BL/GR8	0.608	0.239	0.436	95.5	0.186	0.577	0.151	0.470	0.054	0.012	0.015
BL/GR9	1.74	0.396	1.29	89.1	0.317	0.610	1.28	1.87	0.148	0.012	0.014
BL/GR10	1.40	0.827	0.716	89.5	0.319	0.191	0.505	2.55	0.112	0.015	0.0020
Egyptian Blue Frit Cake											
BLUE12	0.000	0.176	0.218	70.9	0.202	0.109	0.164	14.6	0.000	0.000	0.000

Color Reference Vessels	Fe_2O_3	CoO	NiO	CuO	ZnO	As_2O_3	Rb_2O	SrO	ZrO_2	Ag_2O	SnO	Sb_2O_5	PbO
YELLOW4	0.672	0.0085	0.0062	0.035	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.753	4.47
BLACK4	1.71	0.118	0.119	0.130	0.049	0.000	0.000	0.053	0.034	0.000	0.000	0.102	0.021
WHITE14	0.629	0.000	0.000043	0.0018	0.013	0.000	0.000	0.0034	0.00099	0.000	0.000	0.000	0.029
YELLOW5	1.73	0.000	0.00092	0.028	0.000	0.000	0.000	0.000	0.042	0.000	0.285	1.97	4.10
WHITE15	0.828	0.000	0.0040	0.0066	0.014	0.000	0.000	0.0048	0.012	0.000	0.000	0.000	0.026
WHITE16	0.442	0.000	0.0023	0.049	0.017	0.012	0.000	0.0094	0.011	0.000	0.061	0.434	0.010
YELLOW6	0.717	0.000	0.00080	0.011	0.0069	0.000	0.000	0.000	0.000	0.055	0.000	0.347	1.04
GRAY4	0.339	0.000	0.000028	0.0054	0.0055	0.016	0.000	0.0050	0.010	0.000	0.000	0.000	0.006
BROWN8	4.56	0.000	0.040	0.216	0.000	0.000	0.000	0.000	0.000	0.000	0.862	5.51	16.5
BLUE11	1.34	0.069	0.010	0.330	0.0076	0.000	0.000	0.0065	0.000	0.000	0.000	0.041	0.150
BROWN9	0.577	0.000	0.0026	1.55	0.0044	0.000	0.000	0.0086	0.000	0.000	0.085	0.037	0.064
BL/GR7	0.103	0.000	0.0018	1.66	0.0028	0.000	0.000	0.0055	0.000	0.000	0.059	0.0096	0.042
BLACK5	1.83	0.000	0.012	3.25	0.019	0.010	0.000	0.055	0.000	0.000	0.200	0.000	0.064
BL/GR8	0.071	0.000	0.0015	1.45	0.0037	0.0011	0.000	0.0062	0.000	0.000	0.033	0.000	0.012
BL/GR9	0.587	0.000	0.0040	2.64	0.018	0.0042	0.000	0.013	0.016	0.000	0.000	0.000	0.0031
BL/GR10	0.525	0.000	0.0063	3.28	0.021	0.0032	0.000	0.012	0.00020	0.000	0.000	0.000	0.0027
Egyptian Blue Frit Cake													
BLUE12	0.544	0.000	0.017	11.0	0.0062	0.000	0.000	0.082	0.000	0.000	1.92	0.000	0.025

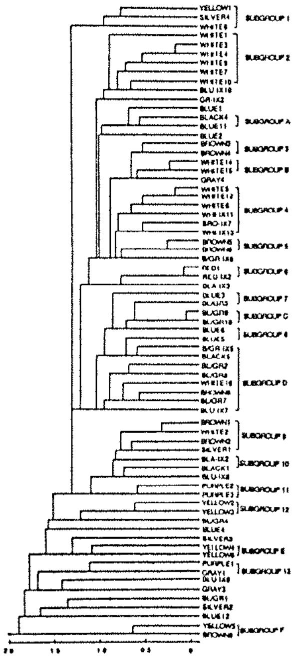

Fig. 10. Dendrogram of Beth Shan silicate small object and vessel specimens.

than absolute differences in elemental concentrations are thereby calculated.[24,47]

By plotting the cophenetic correlation matrix against the cluster analysis, the significance level of the clustering can be determined (shown at the top and bottom on Fig. 10). Linkages between specimens at a distance of 1.0 or greater are less significant, which is particularly evident on the lower half of the graph where several specimens of different colors are grouped together. Such linkages are partly a result of the hierarchical algorithm employed and the two-dimensional representation of a calculation carried out in sixteen-dimensional space (the correlation matrix, not published here, provides an additional check on chemical similarity). More importantly, the amount of each element included in the clustering routine is not directly related to the quantity of a given colorant. Silicate materials are highly complex mixtures of different ingredients—silica, fluxes such as alkalis, stabilizers such as alkaline earths, colorants, etc. Ingredients other than colorants could have contained heavy

metals, albeit at trace or minor levels, which contributed to the observed clustering. For example, the linkages between different colors on the same artifact (BROWN1 and WHITE2; BROWN2 and SILVER1; BRO-IX7 and WHI-IX13) might be plausibly explained by similar base glasses having been used in their production. Their chemical similarity might be further enhanced by the limited migration of colorant ions from one color to the other during firing, with little visible effect on coloration. However, because the end-products of these anomalous groupings are totally fused materials (glass or glaze), with randomly distributed ions, it was not possible to disentangle the numerous variables by lower level statistical analyses (e.g., multiple correlation factors and histograms—see below). Apart from these several anomalous groupings, the individual colors of the small object and vessel collections are distinguishable, as follows:

a. Three blue colorants could be defined in the small object collection: cobalt aluminate, cupric ion blue-green/blue, and Egyptian Blue frit (copper calcium silicate). On the dendrogram, two small object cobalt blues (BLUE1 and BLUE2) fall to either side of Vessel Subgroup A (BLACK4 and BLUE11), also characterized by high levels of cobalt. All the cobalt blue specimens are clearly distinct from cupric blue-green and Egyptian Blue subgroups (e.g., BLUE3 and BL/GR3—Small Object Subgroup 7; BLUE5 and BLUE6—Small Object Subgroup 8). Differing amounts of antimony, used as an opacifier (see below), account for the divergence of several specimens (e.g., cobalt blue BLUE-IX8 and BLUE-IX10, the latter clustering with a large Subgroup 2 of small object antimony whites; cupric B/GR-IX6, BL/GR4, BLUE4, and BL/GR1; Egyptian Blue BLU-IX9) from the primary groupings.

A cake fragment of Egyptian Blue frit (BLUE12), as might be anticipated for a highly concentrated colorant, contains greater amounts of calcium (14.6%), copper (11.0%), and tin (1.92%) than do the Egyptian Blue small objects (averaging 13.4%, 4.3%, and 0.31%, respectively); although only a single sample was analyzed, the cake specimen also appears to be depleted in trace elements apart from lead (0.025%). Consequently, the cake fragment specimen is separate from the Egyptian Blue small object Subgroup 8, as well as cupric blue-green/blue specimens, on the dendrogram. Calcium generally exceeds the stoichiometric equivalency with copper (ratio of 0.71:1) in Egyptian Blue specimens from LB Palestine,[43] indicating that additional lime was added to the frit batch mixture.

The small object and vessel blues are chemically more similar to one another than any other colorants in the corpus. For example, the single example of a vessel cobalt blue (BLUE11) is close to two of the small object cobalt blues (BLUE1 and BLUE2) on the dendrogram, each of the three specimens containing minor amounts of copper. The multiple correlation of cobalt to nickel and zinc is quite high for the small object cobalt blue specimens ($R^2 = 0.62$, and considerably less for cobalt to manganese ($R^2 = 0.20$). The vessel cobalt blue has elevated amounts of the same elements.

The cupric blue-green colorant (BL/GR7 and BL/GR8) on two faience vessels fall to either side of two other vessel colorants

(WHITE16 and BROWN9) in Vessel Subgroup D, which also includes small object cupric blue-green (BL/GR2) and Egyptian Blue (BLU-IX7) specimens. Minor amounts of tin oxide occur in all the specimens. The copper in the vessel blue-greens, however, shows no correlation with arsenic and iron, as do the small object blue-greens ($R^2 = 0.53$); on the other hand, the vessel blue-greens have relatively higher levels of lead.

The two cupric blue-green glazes on pottery (BL/GR9 and BL/GR10—Vessel Subgroup C) are close to cupric (BLUE3 and BL/GR3) and Egyptian Blue (BLUE6 and BLUE5) Small Object Subgroups 7 and 8, respectively, on the dendrogram. They are essentially of the same chemical composition as the cupric glazes on the faience vessels, except that they have higher copper contents (mean of 2.96%) and lower arsenic and iron levels.

In order to understand more fully the clustering on the dendrogram, lower level analyses were routinely carried out. Multiple correlation factors between different elements and bivariate scatter plots, which have been referred to above, were calculated using programs P1R and P6D in the BMDP Biomedial Computer Package.[48] Histograms for each element were generated by the P5D program, and provided a check on the consistency of the data.

For the copper-colored small objects, a histogram of copper oxide contents on a logarithmic scale exhibited a bimodal normal distribution, which is typical of elements which are present at both trace/minor and major levels (also observed for iron, manganese, cobalt, silver, and lead). One copper peak was centered at about 0.02%, and the other around 3%. The lower value represents the trace amount deriving from the various raw materials, whereas the upper amount results from the use of copper as a separate additive for coloration, apparently according to a standard recipe.

Since tin is often thought to have entered LB glasses and glazes unintentionally with bronze additives, this hypothesis was tested by calculating the relative tin oxide content (tin oxide divided by tin oxide plus copper oxide) of all the samples with copper and tin contents above a trace level (0.1%). Both the vessel and small object collections had values in two ranges: 0.001-0.002 (9 small objects and 2 vessels) and 0.03-0.06 (3 small objects and 2 vessels). Additionally, five small objects and two vessels had relative tin oxide contents exceeding 0.10. Indeed, the relative contents of a purple glaze (PURPLE1—Small Object Subgroup 13) on a small object, and a yellow glass (YELLOW5) and brown glaze (BROWN8) on two vessels (Vessel Subgroup F) were above 0.90.

Although the relative tin oxide content does not serve to distinguish the small object colorants from the vessel colorants, the presence of tin in glasses and glazes before the Roman period is unusual and requires an explanation. Given the high absolute amounts of tin in these examples (generally between 0.1 and 0.3%), deliberate addition is implied (Ref. 42, pp. 88-93; cf. Ref. 49) rather than differential leaching, oxidation enrichment,[50] interference between the two elements, and/or instrumental sensitivity. Since tin is known to have been transported in ingot form during the LBA[51] and added separately to copper, this possibility cannot be excluded for silicates. Most of the tin in the glasses and glazes from Beth Shan probably entered unintentionally as bronze refuse used as a copper colorant, since the relative tin oxide content of the majority of the specimens accords with the relative tin content (tin divided by tin plus copper) of LB II bronze artifacts from the site—4.10%. Occasionally, tin appears to have been added in a richer form, perhaps to achieve a glossier appearance (Ref. 42, pp. 93-94).

b. The color brown of Beth Shan small objects and vessels was achieved by manganese in the +3 oxidation state or lead antimonate in the presence of iron. Two manganese browns (BROWN9 and BLACK5—Vessel Subgroup D on Fig. 10) were represented on faience vessels, and they are chemically different from the two small object manganese brown subgroups (BROWN3 and BROWN4—Subgroup 3; BROWN1, WHITE2, BROWN2, and SILVER1—Subgroup 9), which are differentiated by their relative amounts of iron. The "black" glaze (BLACK5) on one faience vessel is a very dark brown, containing 5.25% manganese oxide. Small amounts of lead (mean of 0.06%) and tin (0.14%) in the vessel manganese browns are absent from the small object browns. Manganese also correlates with nickel and zinc ($R^2 = 0.83$) in the small object browns, whereas the vessel browns show no correlation between these elements.

c. The basic composition of lead antimonate yellow or brown (when the iron content is elevated) is the same for both collections. On average, the ratio of antimony pentoxide to lead oxide in the small objects is 1.51:1, which is very close to the 1.4:1 stoichiometric ratio. The lead/antimony ratio of the vessels (3.45:1), on the other hand, is two and half times that of the stoichiometric ratio, indicating a large excess of lead. Three small objects (YELLOW1, YELLOW3, and BRO-IX7) contain excess antimony, and minor amounts of manganese, which accentuates the coloration, occur in one small object (BROWN6) and one vessel (YELLOW4).

Primarily because of differing lead/antimony ratio and the presence of zinc as a trace or minor element (as much as 0.323%; correlation of $r^2 = 0.60$ with lead) in the small object lead antimonates and its absence from the vessel lead antimonates, the two vessel subgroups (YELLOW4 and YELLOW6—Vessel Subgroup E; YELLOW5 and BROWN8—Vessel Subgroup F) cluster separately from the bead and pendant subgroups (BROWN5 and BROWN6—Small Object Subgroup 5; YELLOW2 and YELLOW3—Small Object Subgroup 12). The two vessel subgroups can be explained by the presence or absence of tin, which is as high as 0.862% in one specimen (BROWN8).

d. White Coloration of the small objects is exclusively the result of calcium antimonate.[49] Excluding four specimens (WHITE3, WHITE4, WHITE5, WHITE12) which had anomalously high amounts of antimony and contained no calcium (perhaps as a result of leaching), the antimony pentoxide to calcium oxide ratio for the remaining nine specimens was exactly the 1.1:1 stoichiometric ratio. Only one such white (WHITE16) was observed on a vessel, which is separated from two small object Subgroups 2 and 4 on the dendro-

(WHITE16 and BROWN9) in Vessel Subgroup D, which also includes small object cupric blue-green (BL/GR2) and Egyptian Blue (BLU-IX7) specimens. Minor amounts of tin oxide occur in all the specimens. The copper in the vessel blue-greens, however, shows no correlation with arsenic and iron, as do the small object blue-greens (R^2 = 0.53); on the other hand, the vessel blue-greens have relatively higher levels of lead.

The two cupric blue-green glazes on pottery (BL/GR9 and BL/GR10—Vessel Subgroup C) are close to cupric (BLUE3 and BL/GR3) and Egyptian Blue (BLUE6 and BLUE5) Small Object Subgroups 7 and 8, respectively, on the dendrogram. They are essentially of the same chemical composition as the cupric glazes on the faience vessels, except that they have higher copper contents (mean of 2.96%) and lower arsenic and iron levels.

In order to understand more fully the clustering on the dendrogram, lower level analyses were routinely carried out. Multiple correlation factors between different elements and bivariate scatter plots, which have been referred to above, were calculated using programs P1R and P6D in the BMDP Biomedial Computer Package.[48] Histograms for each element were generated by the P5D program, and provided a check on the consistency of the data.

For the copper-colored small objects, a histogram of copper oxide contents on a logarithmic scale exhibited a bimodal normal distribution, which is typical of elements which are present at both trace/minor and major levels (also observed for iron, manganese, cobalt, silver, and lead). One copper peak was centered at about 0.02%, and the other around 3%. The lower value represents the trace amount deriving from the various raw materials, whereas the upper amount results from the use of copper as a separate additive for coloration, apparently according to a standard recipe.

Since tin is often thought to have entered LB glasses and glazes unintentionally with bronze additives, this hypothesis was tested by calculating the relative tin oxide content (tin oxide divided by tin oxide plus copper oxide) of all the samples with copper and tin contents above a trace level (0.1%). Both the vessel and small object collections had values in two ranges: 0.001-0.002 (9 small objects and 2 vessels) and 0.03-0.06 (3 small objects and 2 vessels). Additionally, five small objects and two vessels had relative tin oxide contents exceeding 0.10. Indeed, the relative contents of a purple glaze (PURPLE1—Small Object Subgroup 13) on a small object, and a yellow glass (YELLOW5) and brown glaze (BROWN8) on two vessels (Vessel Subgroup F) were above 0.90.

Although the relative tin oxide content does not serve to distinguish the small object colorants from the vessel colorants, the presence of tin in glasses and glazes before the Roman period is unusual and requires an explanation. Given the high absolute amounts of tin in these examples (generally between 0.1 and 0.3%), deliberate addition is implied (Ref. 42, pp. 88-93; cf. Ref. 49) rather than differential leaching, oxidation enrichment,[50] interference between the two elements, and/or instrumental sensitivity. Since tin is known to have been transported in ingot form during the LBA[51] and added separately to copper, this possibility cannot be excluded for silicates. Most of the tin in the glasses and glazes from Beth Shan probably entered unintentionally as bronze refuse used as a copper colorant, since the relative tin oxide content of the majority of the specimens accords with the relative tin content (tin divided by tin plus copper) of LB II bronze artifacts from the site—4.10%. Occasionally, tin appears to have been added in a richer form, perhaps to achieve a glossier appearance (Ref. 42, pp. 93-94).

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d. White Coloration of the small objects is exclusively the result of calcium antimonate.[49] Excluding four specimens (WHITE3, WHITE4, WHITE5, WHITE12) which had anomalously high amounts of antimony and contained no calcium (perhaps as a result of leaching), the antimony pentoxide to calcium oxide ratio for the remaining nine specimens was exactly the 1.1:1 stoichiometric ratio. Only one such white (WHITE16) was observed on a vessel, which is separated from two small object Subgroups 2 and 4 on the dendrogram because of its lower antimony content (0.434%), a somewhat elevated tin and lead content (0.061% and 0.010%, respectively), and the lack of correlation between antimony and the trace elements titanium and iron. The vessel white clusters with various other vessel colors (brown, black, blue-green, and blue in Vessel Subgroup D), which have similar levels of tin.

Calcium antimonate was also used as an opacifying agent for other small object colorants,[52,53] viz., cupric blue-green, manganese brown, and cobalt blue. Antimony pentoxide amounts range as high as 8.25% (BLU-IX-7), and average 2.02%. Only one of the vessel colorants, a black (BLACK4), had been opacified with 0.104% antimony.

Two of the whites on the vessels (WHITE14 and WHITE15—Vessel Subgroup B) totally differed from the small object calcium antimonate whites in that the white was the result of a depletion of all heavy metals and devitrification of the silica matrix (the glass was probably originally transparent). Very pure sand and other raw materials must have been exploited or prepared, to prevent contaminants, such as iron, from entering batch mixtures. The specimens had elevated potassium levels (mean of 2.12%), which might have been derived from a plant source.

A gray colorant on a vessel (GRAY4) clusters with the depleted vessel whites (Vessel Subgroup B). Three small object blacks (BLA-IX3, BLA-IX2 and BLACK1—Small Object Subgroup 10) are also comparable in lacking any heavy metal colorant, although they cluster separately; their coloration is possibly due to elemental carbon (not detected by PIXE), as suggested by the elevated levels of two elements often associated with organic materials—potassium and/or strontium. Iron sulphide[54] is less probable as the colorant, since iron and sulphur are present in only trace amounts. One small object specimen (BLA-IX2) has an elevated manganese level, which would have contributed to a darker color.

e. A black colorant (BLACK4—Vessel Subgroup A) on one vessel was achieved by a combination of elevated levels of the oxides of copper (0.130%), manganese (2.41%), and cobalt (0.118%). Purple (PURPLE1) and gray (GRAY1) glazes on two pendants (Small Object Subgroup 13) are similar, but have higher mean levels of cobalt (0.21%) and reduced amounts of manganese (0.18%) and copper (0.08%). Two additional small objects (BROWN1—Small Object Subgroup 9; GRAY3) are high in manganese and copper, but lack cobalt.

f. Several colorants were unique in the small object collection: hematite red (RED1 and RED-IX2—Small Object Subgroup 6), and a silver colloid producing a silvery color (SILVER2, SILVER3, and SILVER4) or a purple when a small amount of additional cobalt (PURPLE2 and PURPLE3—Small Object Subgroup 11) is present. The silver content of the silver colloidal colorants, which are dispersed as particles (up to one micron in diameter) in the vitreous matrix, is as high as 0.770%. The silver correlates most closely with titanium and manganese as trace elements (R^2 = 0.42). A lead antimonate yellow (YELLOW1) and a calcium antimonate white

(WHITE8), which contain trace amounts of silver, cluster with one of the silver colloid specimens (SILVER4) as Small Object Subgroup 1. No example of cuprous red was recorded.

The absence of hematite red and silver colloid colorants in the vessel collection may well be due to limited sampling. Another difference between the small object and vessel colorants, however, is probably more significant. The sulphur level of the vessel colorants (mean of 3.39%) is higher than that of the small object colorants (mean of 0.49%), suggesting that the vessel colorants might derive from sulphide ores, whether of copper, lead, antimony, manganese, or cobalt. This explanation, however, fails to account for the elevated sulphur content (mean of 3.13%) of vessel whites and grays, which are depleted in heavy metals.

In summary, the minor elements associated with the colorants of the Egyptian-style and Palestinian small objects (beads and pendants) were different from those of the vessels, which were exclusively Egyptian in style. The minor elements (specifically, lead and/or tin associated with lead antimonate yellow/brown, calcium antimonate white, cupric blue-green, and manganese-iron brown, and copper associated with cobalt blue) that were more prevalent in the vessel colorants are also characteristic of vessel glazes and glasses on vessels definitely made in New Kingdom Egypt (Ref. 42, pp. 84–88, 110–12). One colorant, a white resulting from the depletion of all heavy metals and devitrification, occurs only on the vessels, and comparable transparent glazes are documented in Egypt (Ref. 42, pp. 145–46).

Since a very large, representative collection of small objects from Levels VII and VIII was analyzed, it is difficult to account for the consistent differences between the chemical profiles of most of the main colorants of the small objects and the vessels, as well as the absence of a depleted white among the small objects, unless the latter, even those of Egyptian style, had been made locally. On the other hand, the faience and core-formed glass vessels, which would have demanded much more technical expertise to manufacture, were most likely made in Egypt and exported to Beth Shan. The chemical inference is supported by a paucity of such vessels in Palestine, the absence of an industrial installation (such as at el-Amarna[55]) or manufacturing debris in Levels VII and VIII, and their Egyptian stylistic affinities.

Local production of Egyptian-style faience small artifacts, especially beads and pendants, would have been facilitated by an already-established Palestinian glass industry. Some Egyptian craftsmen, however, must also have been present, in order to account for the very close stylistic and technological characteristics of the Egyptian-style beads and pendants from Levels VII and VIII to those of New Kingdom Egypt. Its manufacture at Beth Shan can be inferred from pieces of misshapen and overfired glass and faience, a cake fragment and other pieces of Egyptian Blue frit colorant, and a mold for a fluted bead or inlay. The necessary raw materials, including silica sand, alkali fluxes, lime, and many of the metals for colorants (in particular, copper and manganese), were readily available in Palestine. Some metal colorants would have to have been imported, e.g., cobalt blue from the oases of the Western Desert of Egypt, according to the minor and trace element chemical profile (nickel, zinc, and manganese) of Level VII/VIII glasses and glazes.[56] The probable adoption and importation of foreign colorants and opacifiers has been documented for other Eastern Mediterranean silicate industries (e.g., Crete[57]; Egypt[58]).

The large increase in the percentage of faience in Levels VII and VIII, like the prevalence of more heavily tempered, low fired pottery wares (above), again points to considerable Egyptian influence in the silicate industry. Syro-Palestinian overglazes onto effloresced, low-fired faience surfaces may represent an instance of technological coalescence, although the same technique was already being practiced a century earlier in Egypt.[42]

Conclusions

In attempting to reconstruct how the Egyptian and Palestinian ceramic industries interacted in Levels VII and VIII at Beth Shan, the paucity of written sources and archaeological data relating to the industries and the community in general are serious limitations. For example, an important consideration, about which little is known, is whether Palestinian and Egyptian workshops were separate from one another both in organizational control and output, with the former continuing to produce large quantities of Palestinian pottery as it had in the past and the latter supplying Egyptian-style pottery and objects. In a broader sense, to what extent did Palestinians adopt or modify Egyptian culture, and Egyptians Palestinian culture?; and how did this impact on the ceramic industries at the site?

The available evidence, specifically the undirectional technological and stylistic changes in the Palestinian ceramic industries which brought them into conformity with Egyptian practices, suggests that, even if the two groups had separate workshops, the Egyptians were in control at the most basic level—the preparation and supply of raw materials (heavily tempered clays and faience). Given the physical and chemical properties of these materials, Palestinian ceramic specialists might then have adopted concomitant Egyptian techniques (rough trimming of Palestinian pottery vessel exteriors, and uniformly low-temperature firings of pottery and silicate artifacts). Whether as a voluntary or forced response, innovation by Palestinian craftsmen (such as combining the features of a principal Canaanite goddess with an Egyptian snake deity by employing Egyptian fabrication techniques, or overlaying Palestinian glazes onto low-fired faience bodies) is also more likely under such circumstances. They had the necessary expertise in both technologies, and Levantine craftsmen, situated in the middle of the then civilized world, had long been exposed to different technologies and styles, which sometimes led to the production of composite types. The emergence of a synchretistic Egyptian and Palestinian cult at the site would have encouraged this development. Although Egyptians during the New Kingdom were more open to the assimilation of Syro-Palestinian technology and culture than perhaps at any time in their history, the pottery and

silicate industries in Egypt itself were generally conservative in the materials and techniques employed.[40,58–59] To be sure, elaborate, polychrome jewelry, tiles, and vessels were also improvised, but the few documented examples combining Egyptian and foreign stylistic elements come from areas where large groups of foreigners were resident and where foreign craftsmen might therefore have manufactured the pieces (e.g., the Delta and el-Amarna). Lacking evidence to the contrary, any Egyptian craftsmen at Beth Shan probably perpetuated the conservative attitudes of their homeland.

A final point worth considering is the lack of Egyptian influence in other Beth Shan local industries, such as metals, alabaster- and bone-working. Like the early second millennium B.C. Assyrian trading colony at Kültepe in central Anatolia,[60] the Egyptian colonization of Beth Shan might have been archaeologically invisible if only the standard Palestinian products of these industries had been preserved. Possibly, ceramic industries were considered more central to Palestinian and Egyptian cultural life, especially since a large percentage of the cultic vessels recovered from Levels VII and VIII were made from pottery and silicate materials. The low socio-economic status of many ceramic specialists in societies around the world today need not have been the case in antiquity. The materials themselves, as the earliest manmade synthetics, were viewed as almost miraculous replications of naturally occurring minerals, metals, and other substances, often associated with specific deities (e.g., blue-green glazed faience duplicated turquoise, the semi-precious stone almost synonymous with Hathor). Khnum, an Egyptian god of creation, is depicted in New Kingdom reliefs as making pottery vessels and divine figures on a turntable[61]; in Egyptian mythology, Khnum created all living creatures in this fashion. The association between ceramics and Palestinian cultural life was just as intimate, as illustrated by the faience factories attached to Syro-Palestinian and Mesopotamian temples and palaces in the LBA.[62] If ceramics were more central to both Egyptian and Palestinian culture, then changes, whether by direct borrowing, imposition, or innovation, are more apt to reflect technological and stylistic exchange between the two cultures.

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