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SILICATE INDUSTRIES OF LATE BRONZE-EARLY IRON PALESTINE: TECHNOLOGICAL INTERACTION BETWEEN EGYPT AND THE LEVANT

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Abstract

The study is based on the largest silicate collections of the Late Bronze Age from well-dated excavations east and west of the Jordan River - the Baq'ah Valley on the Transjordanian plateau, and Beth Shan at the juncture of the Jezreel and Jordan Valleys. Samples were studied under low and high powder (SEM) magnification to characterize the materials and their state of preservation. Extensive multivariate evaluation by correlation, factor, and cluster analysis of compositonal data for the glazes and glasses, obtained by proton-induced x-ray emission (PIXE) spectroscopy, revealed very little overlap between the two groups. Elevated levels of transition metal colourants and opacifiers were used primarily for highly vitrified frits, in addition to glass, in the Baq'ah. At Beth Shan, lesser amounts of these metals were employed in different combinations and sometimes with different trace and minor element profiles, which implied a separate Syro-Palestinian glass/frit tradition. At the latter site, Syro-Palestinian colourants were also applied as overglazes on effloresced, low-fired faience bodies. Thus, two different technological traditions, the one at Beth Shan representing an accommodation to Egyptian practice, were attested within a distance of fifty kilometers.

Keywords: BAQ'AH VALLEY, BETH SHAN, COLOURANTS, EGYPT, FAIENCE, FRIT, GLASS, GLAZE, OPACIFIERS, PALESTINE, PIXE, SEM, SILICATE TECHNOLOGY, SYRIA, TRANSITION METALS

Introduction

Palestine, comprising modern-day Israel and Jordan, lies on the southern periphery of the greater Syro-Palestine region. Previous studies of silicate collections from sites to the north, in particular Nuzi (Vandiver 1982), have demonstrated that experimentation in glass and frit began at least by 1600 BC, near the end of the Middle Bronze Age (cf.Oppenheim *et al.* 1970). Particularly noteworthy about this experimentation was the variety of metal colourants and opacifiers used.

Archaeological investigation in Palestine has revealed that the country participated fully in the Middle Bronze-Late Bronze Age urban civilization (Gerstenblith 1983, Drower 1973; for Jordan, see McGovern 1986a). In addition, the availability of some of the metal ores for colourants there, such as iron (Coughenour 1976), copper (Conrad and Rothenberg 1980), and manganese (Bender 1974), some of which were being exploited contemporaneously, strongly suggests that this area would have contributed directly to the innovations in metallurgical and silicate technology. Deposits of other necessary raw materials for silicate production - silica sand and sandstone, alkali salts, and lime - are widely distributed throughout the country.

Besides serving as a monitor for developments in the glass/frit industry, the Palestinian evidence is also potentially of great value as a touchstone for changes in the traditional Egyptian faience industry as the latter came in contact with and was affected by Syro-Palestinian innovations. The Egyptian industry, which initially developed in the Chalcolithic period, remained highly conservative over the next two millennia (Kaczmarczyk and Hedges 1983). Egypt began to interact again significantly with the Levant around 1750 BC with the rise of the Semitic 'Hyksos' dynasties in the Nile Delta, whose material culture was virtually indistinguishable from that of Palestine. Under these circumstances, Palestine would be a natural trading partner with Egypt for raw materials and finished products. Following the return of native Egyptians to power ca. 1550 BC (the beginning of the Late Bronze Age), Palestine played a more subservient role to Egypt as a forward defensive position and erstwhile client state (Weinstein 1981), but this relationship might well have intensified Egyptian contacts. Correspondingly, the New Kingdom faience industry in Egypt proper now evidenced improvisation, particularly in the use of colourants and opacifiers.

Palestinian reference collections

The silicate collections of two Palestinian sites - Beth Shan and the Baq'ah Valey of Jordan (Fig.1) - were studied, in order to elucidate the technological innovation and interaction between different industries in the Late Bronze and Early Iron Ages (ca. 1550-1050 BC).

Beth Shan, which was excavated by the University Museum between 1921 and 1934 (Rowe 1930 and 1940), is one of the most important sites of the period. The massive tell is strategically situated at the juncture of the Jezreel and Jordan valleys at the eastern terminus of the *Via Maris*, the main overland route between Egypt and the Near East. After crossing the shallow fords of the Jordan River here, roads branched off to Damascus and Amman. In recognition of its crucial location, the Egyptians chose Beth Shan as their northernmost frontier post. By 1300 BC, the site had been laid out along Egyptian architectural lines with a temple, 'commandant's house', and fortress (James and McGovern 1986).

The temple and its deposits illustrate how Egyptian and Syro-Palestinian artistic and technological traditions might be blended together at such a border site. The architectural layout of the building - a columned, open forecourt with stairs leading up to a sanctuary (Rowe 1940, pl.4, fig.3) - was very similar to the River Valley shrines at el-Amarna, Akhenaten's capital along the Middle Nile. The temple was very likely jointly dedicated to a female Syro-Palestinian deity (Ashtarte) and Hathor, the Egyptian goddess of turquoise and foreign countries, both of whom are depicted on artifacts from the building.

For the purposes of this study, the most important discovery from the temple was the more than 10,000 beads and 400 pendants in glass, faience, and frit (Fig.2), in addition to vessels of glass, glazed pottery, and faience (McGovern 1986b). Altogether, they represent the largest silicate collection in Late Bronze Age Palestine.

The Beth Shan group, however, lacked well-dated materials for the Late Bronze I period (ca. 1550-1400 BC). This gap was filled by the Baq'ah Valley collection, which also provided Late Bronze II (ca. 1400-1200 BC) and Iron IA (ca. 1200-1050 BC) material. The Baq'ah Valley, a well-watered, fertile depression twenty kilometers northwest of Amman, was one of the more intensively settled areas of Jordan (McGovern 1985a). The main north-south route of antiquity, the King's Highway, probably ran through the center of the valley, with side roads descending through the Wadi Umm ad-Danānīr to the Jordan Valley.

The Baq'ah collection was recovered from burial caves on the northwestern sides of the valley (McGovern 1986a). The corpus is smaller than that of Beth Shan - approximately three hundred beads and pendants for the Late Bronze Age and ten examples for the period after 1200 BC, when the silicate industry apparently fell into decline. Still, it is the largest group thus far excavated in Jordan, and from an area that was influenced minimally by Egypt and thus is an excellent complement of the Beth Shan collection.

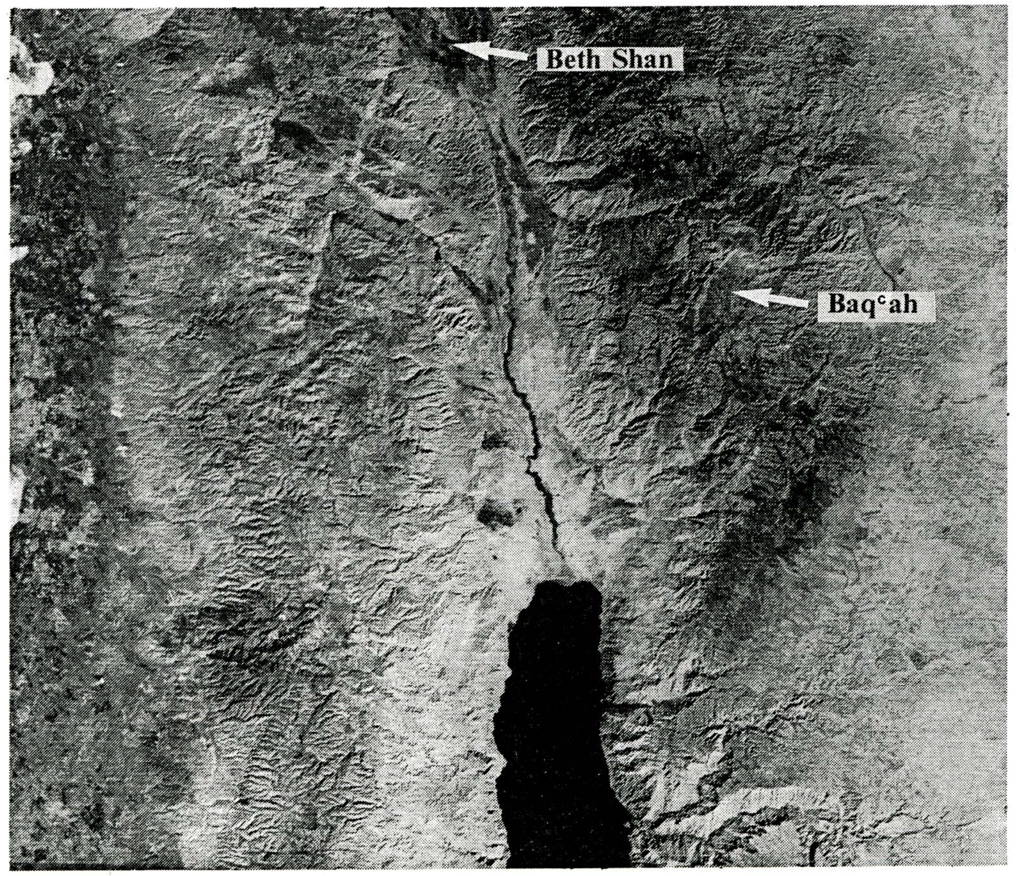

Fig. 1 LANDSAT Satellite photograph from an altitude of 900km. The Dead Sea appears at the bottom, and the Mediterranean is just visible to the left. The Baq'ah stands out as a flat elliptical area, a unique geomorphological feature on the central Transjordanian plateau at the intersection of three flexures in the earth's crust.

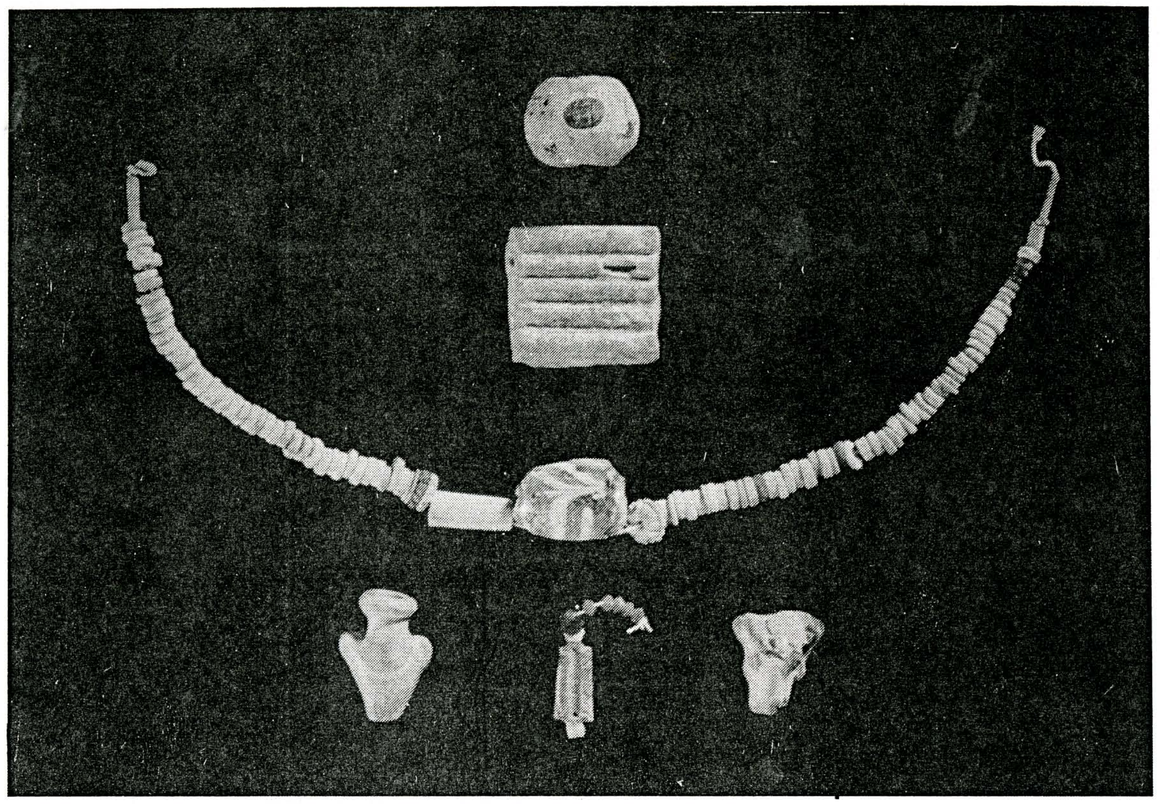

Fig. 2 Representative examples of beads and pendants from the Beth Shan collection. At the bottom, from left to right, are shown an *ib* ('heart') pendant (YELLOW1 and WHITE1), a pendant possibly depicting reeds (BLUE3), and a ram's head pendant (WHITE3, WHITE4, BROWN2, and SILVER1). In the middle of the string of beads is a large barrel-shaped bead with a feather or ogee pattern in antimonate white (WHITE10), and whose base glass is coloured with a silver colloid (SILVER3 and SILVER4). Above a bead spacer, an eye bead is shown at the top; the brown (BRO-1X7) and white (WHI-1X13) eyes are impressed into a blue-green (B/GR-1X6) surface (black, BLA-1X3, on the interior).

Sampling and analytical techniques

Macroscopic and low-power microscopic examination allowed materials (glass, frit, faience, glassy faience) to be characterized preliminarily, fabrication techniques defined, larger inclusions noted, and the extent of weathering determined. Fifty-four Beth Shan (Table 1) and twenty-eight Baq'ah (Table 2) small artifacts (beads and pendants) were selected as being sufficiently intact and representative of the range of variation for further analysis. A definitive characterization of the materials, including their vitrification structures and inclusions, was then carried out using a scanning electron microscope (SEM) with an attached energy dispersive system (EDS) for semi-quantitative chemical determination. Both original surfaces and prepared cross-sections were examined.

More precise chemical determinations of glasses and glazes covering faience and frit was done by proton-induced x-ray emission spectroscopy (PIXE). 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 0.5mm, which is quite adequate for a material whose homogeneity has been checked independently; there is relatively little *Brehmstrahllung* background, especially as compared with electron or x-ray spectroscopy; since the beam penetrates only about 10-15 microns, the method is essentially non-destructive; finally, it is very time and cost efficient, since many elements can be measured simultaneously. Corning glass standard B (Brill 1972) was used for calibration. A 1.3 MeV proton beam in a helium atmosphere was used to measure the low atomic number elements. A 2.0 MeV beam in an air or nitrogen atmosphere, in conjunction with potassium chloride, vanadium, and aluminium filters, enabled the elements of higher atomic number to be measured with greater sensitivity (Swann 1982).

Twenty-five elements were typically measured, and the weight percentages were then normalized to a hundred percent. A beryllium window between the sample and the lithium-drifted silicon detector effectively blocked out the lower energy x-rays from elements with an atomic weight less than sodium. Since the latter is at the lower detection limit, several samples were retested by emission spectroscopy as a check; in these instances, the sodium contents were within the one-sigma experimental error of each method.

Experimental results

Sodium appears to have been the primary flux in all the samples (Tables 3 and 4). Nine to ten percent of the oxide was probably typical. Many of the samples, however, have lower sodium values, which is most likely the result of leaching out; otherwise, extremely high temperatures, beyond the pyrotechnological expertise of the period, would have been required to vitrify the silica.

Low potassium values presumably also reflect leaching effects. Thus, the Beth Shan specimens overall averaged 2.75% potassium oxide. Several Beth Shan examples (PURPLE1, BLA-1X2, GRAY3), however, retain as much as 7.26% suggesting the use of a plant ash as a flux. The potassium oxide content of the Baq'ah group is uniformly low, never more than 2.74% and averaging 0.44%. Alkaline earth and aluminium contents for both collections are comparable - approximately 4% aluminium and calcium, and 1% magnesium - in accord with other published results (Brill 1970, Sayre 1965).

The colourants and opacifiers have the most distinctive chemistry of the two collections, and serve to distinguish between them. Computer clustering of log-normalized oxide data (unweighted pair-group method after Rholf *et al.* 1982) for titanium and elements of higher atomic weight shows remarkably little overlap for visually similar colours of each group (Fig.3).

Most notably, the largest Baq'ah subgroup was comprised of dark colours - two grays, two browns, two purples, one black, and one blue-green, clustering together and marked as Baq'ah on Figure 3 - which were the result of elevated levels of copper (average of 1.23%), manganese (average of 1.64%), and cobalt (average of 0.34%), as the oxides. By contrast, only two Beth Shan examples (PURPLE1 and GRAY1) have elevated copper, manganese, and cobalt levels, and these are in noticeably lower amounts than in the Baq'ah group; two additional examples (BROWN1 and GRAY3) were high in manganese and copper. The precise colouration of the objects depends on the relative amount of each element in a specific oxidation state (Bamford 1977), uniformly high amounts of the three elements yielding a gray or black.

Complementary copper-manganese and cobalt-manganese scattergrams (Figs.4 and 5) highlight the prevalence of dark colours in the Baq'ah collection. The Baq'ah specimens, which cluster together, appear in the upper right corner of each graph, reflecting their higher absolute content of the transition metals. Included here are also examples that were high in only one or two of the elements. Thus, only Beth Shan has examples (BLUE1, BLUE2, BLUE-1X8, and BLUE-IX10) of cobalt aluminate blue, which all have trace levels of manganese, placing them in the middle of the copper-manganese scattergram (Fig.4). Zinc and nickel, while not present in large enough quantitites to affect the colouration, show a relatively high correlation (R^2) with cobalt at both sites (for Beth Shan 0.6236; for Baq'ah 0.6057; Fig.6).

The manganese in the manganese browns from Beth Shan correlates with the trace elements nickel and zinc (R^2=0.8286), and two examples (BROWN3 and BROWN4) have only trace levels of copper (cf the minor amounts in BROWN1 and BROWN2). In contrast, the Baq'ah manganese browns show no correlation between manganese and nickel or zinc, and all the specimens (BRO-A2-1, BRO-B3-2, BRO-B3-3, and BRO-B3-5), except one (BRO-B3-4), contain copper as a minor element. All the specimens have iron as an additional trace or minor element; in the presence of manganese, iron would be oxidized to the ferric state, which also produces a brown in tetrahedral co-ordination.

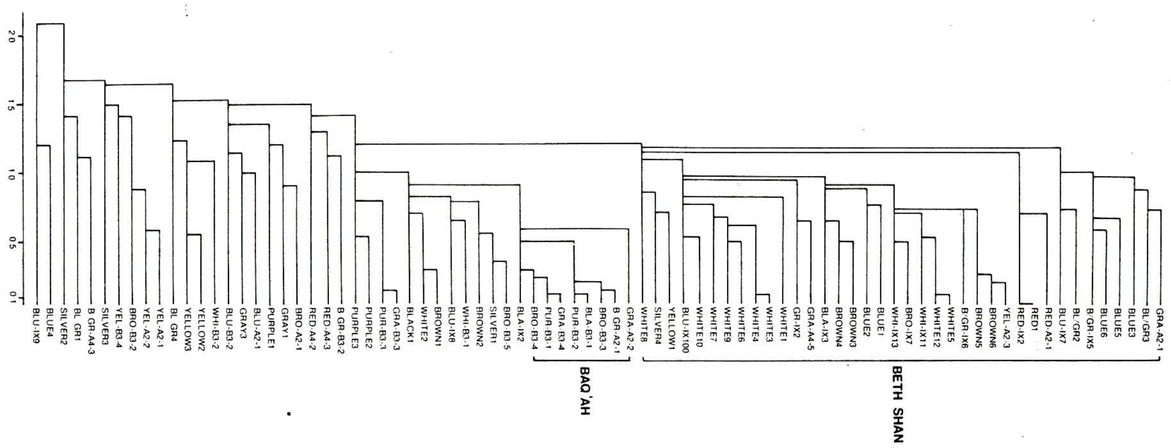

Fig. 3 Dendrogram of Beth Shan and Baq'ah specimens with major subgroups indicated. The oxide data were expressed in logarithms, since many chemical elements appear to be lognormally distributed in nature and the relative rather than absolute changes in the elements are thus measured. The significance level of the clustering (shown at the bottom of the figure) was calculated by plotting the cophenetic correlation matrix against the cluster analysis. Here, specimens that merge at values greater than 0.55 are less significant, accounting for some of the colour mixing on the lower half of the figure. Similar chemical compositions were also observed for different colours on the same example (e.g., BROIX7 and WHI-IX13; WHITE2 and BROWN1; SILVER1 and BROWN2) because of ion migration and possible overlapping of the beam scan.

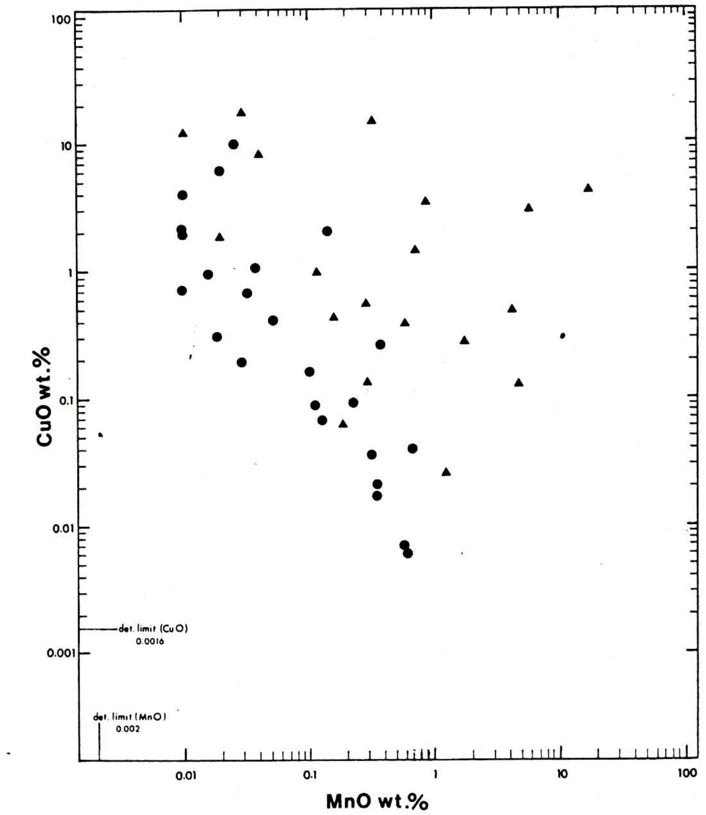

Fig. 4 Copper-manganese scattergram of Beth Shan and Baq'ah specimens, indicated by filled circles and triangles respectively, with more than a trace amount of one or both elements.

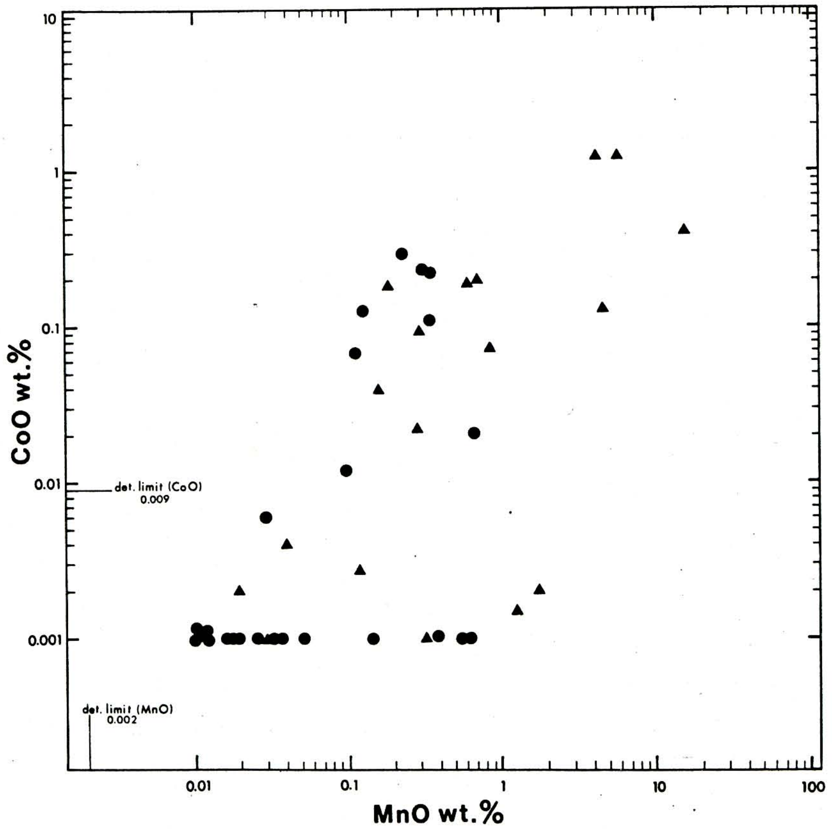

Fig. 5 Cobalt-manganese scattergram of Beth Shan and Baq'ah specimens, indicated by filled circles and triangles respectively, with more than a trace amount of one or both elements.

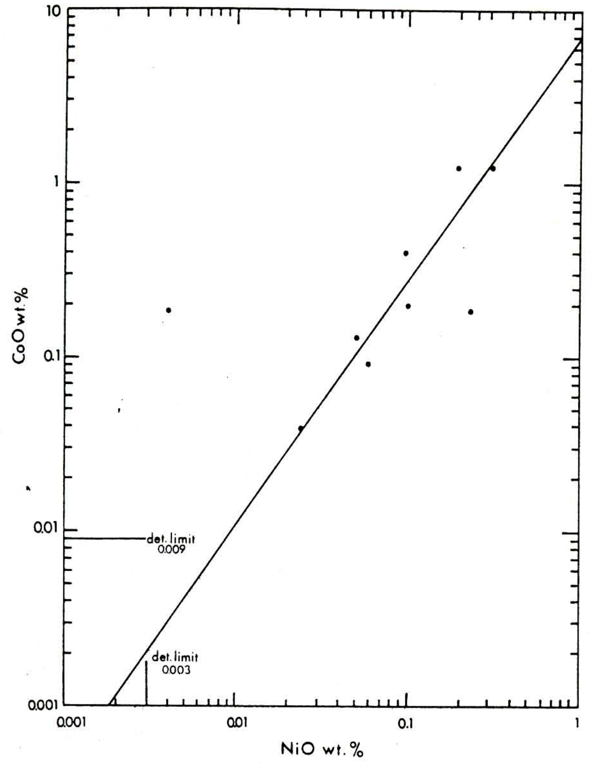

Fig. 6 Regression line for cobalt versus nickel content of Baq'ah samples with a cobalt content greater than a trace amount. Residual mean square of 1.4085.

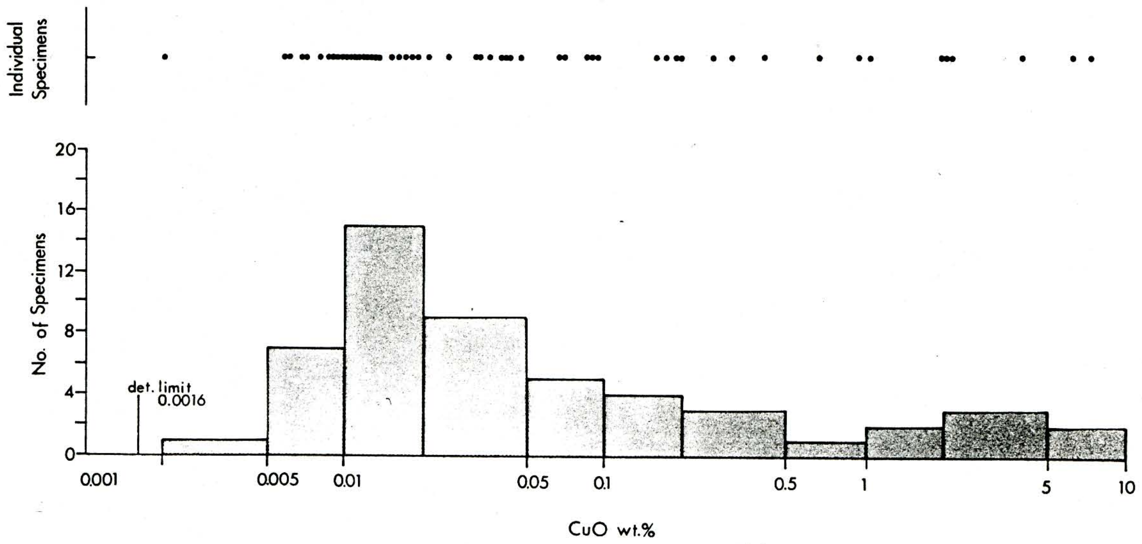

Fig. 7 Histogram of copper contents for the Beth Shan collection on a logarithmic scale. Individual determinations for the fifty-four specimens are shown by dots above the histogram.

Cupric blue-green/blue and Egyptian Blue examples from both sites, which have relatively low cobalt and manganese levels, are closer to the main axes of the scattergrams. All but one of the Baq'ah specimens (B/GR-A2-1) cluster together with the Beth Shan examples, dependent upon the relative amounts of copper, tin as a minor element (up to 1.20%), arsenic and iron as trace elements, and antimony as an opacifier (up to 8.25%). Egyptian Blue frit (copper calcium silicate) clusters out separately if the lower atomic weight elements are included in the statistical analysis. Calcium generally exceeds the stoichiometric equivalency with copper, indicating that additional lime was added to the frit batch mixture.

A histogram of the copper oxide content of all the Beth Shan examples (Fig.7) on a logarithmic scale exhibits a bimodal normal distribution, which is typical of elements that are present at both trace/minor and major levels (also observed for iron, manganese, cobalt, silver, and lead). One copper peak is 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 colouration, apparently according to a standard formula. The corresponding Baq'ah values are approximately 0.03% and 3%. The relative tin oxide content (tin oxide divided by copper plus tin oxides) of the Baq'ah examples, which contain tin and/or copper in amounts exceeding trace levels, was higher than that for the Beth Shan group (Fig.8). In general, both sites have values that group together around 3% and 15%. However, more of the Baq'ah specimens fall in the midrange, and four Baq'ah specimens range between 53% and 97%. The latter (YEL-A2-2, GRA-B3-4, BROWN-B3-4, and RED-A4-3) have fairly high levels of tin (0.102%, 0.147%, 0.078%, and 0.925%, respectively), which are more likely explained by deliberate addition (Kaczmarczyk and Hedges 1983; cf Sayre 1963) than differential leaching or oxidation enrichment (Hedges and Moorey 1975).

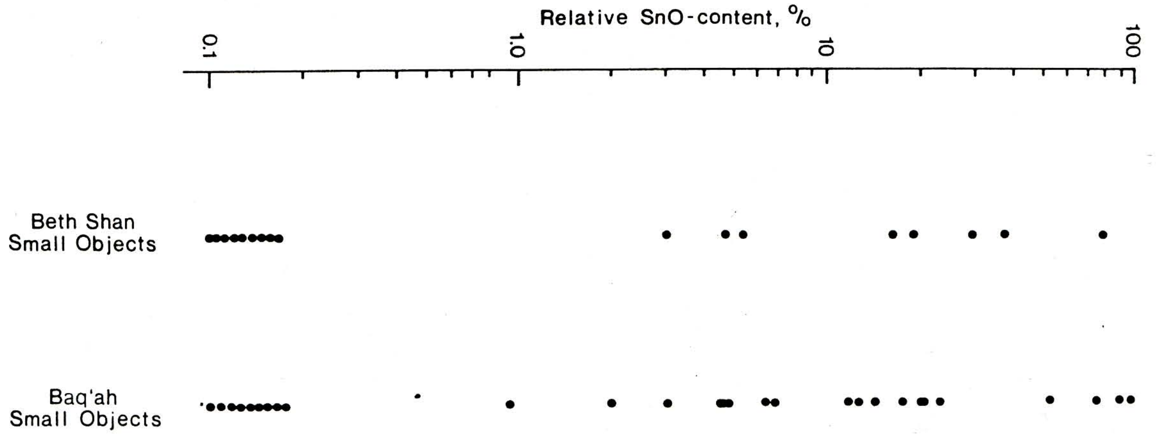

Fig. 8 The relative tin oxide content, i.e. the amount of tin oxide divided by the sum of the tin oxide and copper oxide, for Beth Shan and Baq'ah specimens with a copper and/or tin oxide content above the trace level.

Since tin is known to have been transported in ingot form during the Late Bronze Age (Maddin *et al.* 1977) and added separately to copper, there is no reason to exclude this possibility for silicate materials. The relative tin content (tin divided by copper plus tin) of Baq'ah bronzes for the period from 1550 to 1050 BC averages 9.25%, which is more than twice the Late Bronze II Beth Shan average (4.10%). Thus, most of the tin in the glasses and glazes might well have entered unintentionally as bronze refuse used as a copper colourant, but occasionally tin appears to have been added in a richer form, perhaps to achieve a glossier appearance (Kaczmarczyk and Hedges 1983). At Beth Shan, there was a higher correlation of copper with arsenic as a trace element and iron as a minor element (R^2=0.5267) than in the Baq'ah (R^2=0.0458).

At both sites, white colouration was achieved exclusively by calcium antimonate. The Baq'ah whites (only two examples) have higher antimony levels (average of 16.37%) than the Beth Shan examples (average of 5.60%), and consequently cluster separately. Differences in the amounts of antimony, iron, and titanium account for the two Beth Shan subgroups. Antimony was also used as an opacifier (Sayre 1963) at both sites for cupric blue-green, manganese brown, copper-manganese-cobalt grey (only Baq'ah), cobalt blue (only Beth Shan), and ferric red (only Baq'ah). The values for the Beth Shan corpus ranged very high, up to 8.25% (BLU-IX-7) and averaging 2.02%. Four Baq'ah examples fell within a more typical range of 0.1-0.3% (cf. Sayre 1963, Kaczmarczyk and Hedges 1983). A very slight correlation (R^2 ca. 0.259 between antimony and the trace elements titanium and iron was noted at both sites.

The basic composition of lead antimonate yellow or brown (with elevated iron) was the same at each site. On average, antimony is 3% and lead 4.5%, which converts to an approximately 1:1 stoichiometric relationship. However, sometimes lead is considerably in excess of antimony (e.g. YELLOW2) and vice versa (e.g. YEL-A2-3). A Baq'ah subgroup is segregated out on the dendrogram (Fig.3) because of minor amounts of tin (up to 0.183%). Lead correlated with the trace element zinc at Beth Shan (R^2=0.6045), but not in the Baq'ah.

Red colourants were rare. Two Late Bronze Age examples from Beth Shan averaged 3.90% ferric oxide; a Late Bronze Age Baq'ah example contained 7.03% of the latter. After ca. 1200 BC, a unique variety with as much as 47.96% ferric oxide and 0.73% cobalt (RED-A4-2 and RED-A4-3) appeared in the Baq'ah. The iron is dispersed as spherical particles up to two microns in diameter (cf. Hess and Perlman 1974). No example of cuprous red has yet been documented from either site (cf. Vandiver 1982, Kaczmarczyk and Hedges 1983).

Another unique colourant was a silver oxide at Beth Shan, which gave a silvery colour (SILVER2, SILVER3, and SILVER4) or a purple in the presence of a small amount of cobalt (PURPLE2 AND PURPLE3). The silver content was as high as 0.77%, and dispersed as colloidal particles up to one micron in diameter. The silver correlated most closely with titanium and manganese as trace elements (R^2=0.4199).

Three Beth Shan black specimens (BLACK1, BL-IX2, and BL-IX3) could not have been coloured by one or more of the heavy metals, since they were not present at high enough levels. Possibly, the colouration was achieved by elemental carbon (suggested by elevated levels of potassium and strontium, most likely from an organic source), which is not detected by PIXE. Iron sulphide (Sayre and Smith 1974) is ruled out by iron and sulphur being present in only trace amounts. If reduced carbon is responsible for the black, it is difficult to explain the presence of antimony in the pentavalent oxidation state on one of the examples (WHI-IX11), unless a two-step reduction-oxidation process were employed.

Materials characterization

The majority of the Baq'ah samples are well-fused frits (see Note) with up to 75% glassy phase (Fig.9). Agglomerations of particles or crystals, with a glassy composition and elevated heavy metal levels according to EDS determinations, can be seen embedded in the matrix, particularly in the dark coloured copper-manganese-cobalt and lead antimonate yellow/brown specimens (Fig.10). The particle sizes for the variously coloured frits (up to 50 microns in diameter) and the relative fractions of glass are comparable to similarly coloured frits at Nuzi (Vandiver 1982) and New Kingdom Egyptian Blue examples (Tite *et al.*1984).

The faience at both sites appears to have been made by the efflorescence technique (Tite *et al.* 983) in which salts migrate to the surface during the drying process and are then fired to a glaze (Vandiver 1983). As compared with the rather diffuse glaze boundaries and very little sintering of interior silica particles of the Beth Shan examples (Fig.11), the Baq'ah glazes on both faiences and frits (10-50 microns thick) are much better defined, suggesting that the drying process was more intensive and/or that higher firing temperatures were employed. In turn, the Baq'ah faience is more appropriately described as glassy faience because of its extensive vitrification structure, as compared with the much more limited sintering of silica particles in the Beth Shan faience.

Only cupric blue-green and ferric red faience were effloresced. Other colours (yellow, white, grey, etc), which were first developed within the Syro-Palestinian glass/frit industry, were overlaid as glazes (up to 300 microns thick) onto the effloresced surfaces (Fig.12), probably as liquid slurries, and fired. The latter technique was only observed at Beth Shan, not in the Baq'ah.

Discussion

The rarity of small frit artifacts at Beth Shan and the overlaying of Syro-Palestinian glazes onto low-fired, effloresced faience surfaces there may well represent accommodations to traditional Egyptian practice. In Egypt itself, a conservative tendency in the use of Syro-Palestinian colourants has been noted in the New Kingdom industry (Vandiver 1983, Peltenburg 1974), although glass vessels and elaborate, polychrome jewellery and tiles were also improvised there.

The coalescence of Syro-Palestinian and Egyptian technological traditions at Beth Shan, where a New Kingdom garrison had been set up, is culturally very significant. Perhaps artisans were brought in from Egypt or native craftsmen were trained in Egyptian faience manufacture. Pieces of refuse glass and faience, a large piece of an Egyptian blue cake, and a mould for a fluted bead or inlay from the same contexts as the beads and pendants (James and McGovern 1986) provide evidence for local production of small objects, in addition to the idiosyncratic character of Beth Shan's silicate materials.

Fig. 9 SEM micrograph at 800x of extensive sintering of silica particles on the interior of Baq'ah field no. A2-56 (RED-A2-1), a disc bead.

Fig. 10 SEM micrograph at 1000x of Egyptian Blue frit crystal (the lath - like particle embedded in the glassy matrix, at lower centre) in Baq'ah field no. A2-87 (comparable to field no. A2-102, BLU-A2-1).

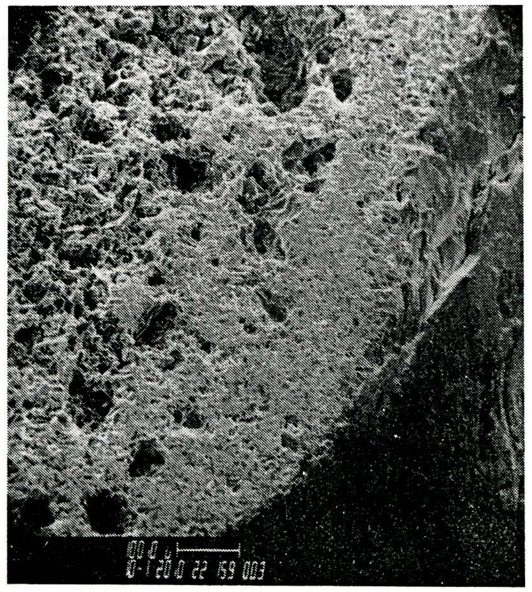

Fig.11 SEM micrograph at 100x of ill-defined faience glaze on Beth Shan field no. 27.11.159a (BL/GR4), a petal or leaf pendant.

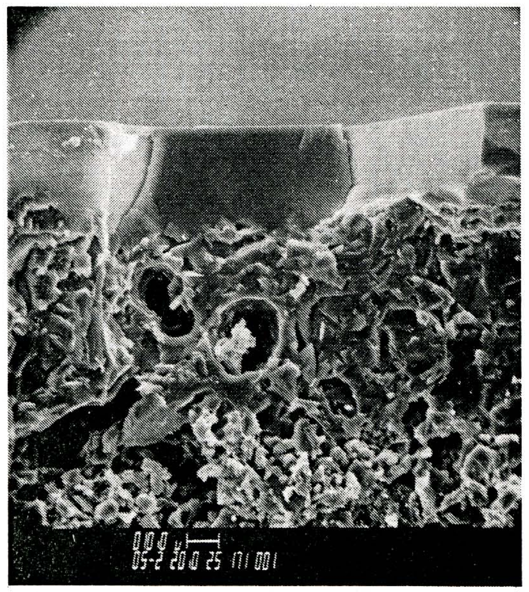

Fig. 12 SEM micrograph at 500x of lead antimonate yellow overglaze (YELLOW3) on copper effloresced glass (GRAY1) of Beth Shan field no. 26.9.171, a petal or leaf pendant. Note poorly vitrified silica particles beneath the glazes.

The probable adoption of foreign colourants and opacifiers has been documented in other Eastern Mediterranean silicate industries (e.g. for Crete see Foster and Kaczmarczyk 1982 and for Egypt see Kaczmarczyk and Hedges 1983). Assuming that the expertise were available, it would be anticipated that native ore deposits would eventually be sought out for producing the same colourants locally. Thus, Palestine has rich copper ore bodies northwest of the Gulf of Aqaba/Eilat (Timna), which were exploited by the Egyptians in the Late Bronze Age. The correlation of copper with arsenic and iron in blue-green/blue glasses and glazes at Beth Shan, which was in close contact with Egypt, suggests that the copper colourants might derive from the Timna deposits (Craddock 1980); in Jordan, where Egyptian connections were minimal, copper did not correlate with these trace elements. However, the complexity of glass and frit batch mixtures, as well as the problem of the partitioning of elements in the smelting process (Tylecote *et al.* 1977), should caution against any precise provenancing of the original ore. Especially in the case of copper ores, which are distributed throughout the Near East and yet have been chemically analyzed only to a limited extent, similar chemical profiles may well exist elsewhere.

The availability of copper and manganese ores in Transjordan may explain their high levels in Baq'ah copper-manganese-cobalt dark colourants. Unless a native source is still to be found, the cobalt must have been imported from Egypt. An alum high in cobalt, with zinc, nickel, and manganese as trace elements, has recently been confirmed for the Dakhla oasis of the Western Desert (Kaczmarczyk, personal communication). Cobalt was accompanied by the same elements in the Baq'ah and at Beth Shan, which implies that Palestine was obtaining its cobalt from Egypt rather than from Iran, where arsenical, manganese-free ores occur (Garner 1956a and 1956b).

The absence of copper-manganese-cobalt dark colourants at Beth Shan and their attestation in Egypt (Kaczmarczyk and Hedges 1983) is more difficult to explain. Again, this may reflect greater Egyptian accessibility to metal ores. Manganese deposits with minor amounts of iron exist in the Eastern Desert (el-Shazly and Saleeb 1959), and the copper from Timna operations might have gone primarily to Egyptian markets.

The antimony and lead trace element profiles of the Palestinian colourants and opacifiers cannot be unequivocably tied to specific ore bodies in the mid-world fold belt in Turkey and Iran (Zwicker 1980, Ryan 1957). Lead-zinc deposits are also found in Egypt (Stos-Gale and Gale 1981).

The several examples of a silver colloid colourant at Beth Shan probably did not derive from Egyptian silver ores where gold generally accompanies the silver (Mishara and Meyers 1974, Prag 1978). Until more chemical analyses of Near Eastern silver deposits are carried out, its provenance must remain unresolved.

As a working hypothesis for the provenance of the iron used in the post-1200 BC red glass, it may be proposed that the glass was reworked iron ore slag, which was a by-product of the contemporaneous iron/steel industry (Pigott *et al.* 1982). A slag sample from the nearby smelting site of Dhahrat Abu Thawab, which yielded early Iron Age sherds in a surface survey, had an elevated cobalt content (as much as 0.33%) that was comparable to the red glass. However, the slag lacked tin, whereas the red glass had a very high amount (0.93%) of the element. Only five beads of the glass were found (McGovern 1986a), suggesting that the glass was not the main goal of production. One example was a horned stratified eye bead in which the white inlays for the eyes were composed of silica particles rather than calcium antimonate, the standard Late Bronze Age material. Silica parting layers were observed along the interior perforations of the beads.

Conclusions

A central Transjordanian silicate industry in small artifacts is strongly implied by the difference in materials, colourants, and opacifiers of the Baq'ah objects when compared with those from Beth Shan, a Jordan Valley site about 50km away. An industrial installation has not yet been located on the Transjordanian plateau, but will be a major goal of future campaigns in the area. On current knowledge, this region pursued its own variant of the Syro-Palestinian glass/frit tradition throughout the Late Bronze Age. As a result of major dislocations in the economy and consequent social pressures (McGovern 1986a), the industry fell into decline around 1200 BC, although a contemporaneous innovative trend was attested by the appearance of a very high-iron red glass.

At Beth Shan, a different variant of the Syro-Palestinian glass/frit industry apparently developed during the Late Bronze Age. After the site was converted into an Egyptian military garrison, faience of standard New Kingdom type became very common, and Syro-Palestinian colourants were applied as overglazes on effloresced faience surfaces. Industrial debris and moulds at the site indicate that artisans, whether Egyptian or native, manufactured small objects locally, and were probably responsible for the merging together of Syro-Palestinian and Egyptian silicate traditions.

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Note

'Frit', according to its modern ceramic definition, is a pre-fused portion of materials, or a glass, which is incorporated into a glaze or glass mixture (Parmelee 1948). Fritting allows highly reactive processes, which might adversely affect glass production, to be carried out beforehand, and enables concentrated, homogeneous materials (such as colourants) to be prepared for easier transport and recipe addition. In the Syro-Palestinian glass/frit industry, frits were often used alone by shaping and refiring the material. The surface particles of the refired frit can fuse to form a glaze, as was observed on many of the Baq'ah fritted examples (cf. the definition of a frit as 'a sintered, polycrystalline body with no glaze coating' in Vandiver 1982).

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Table 1 BETH SHAN ANALYTICAL CORPUS: SILICATE SMALL ARTIFACTS

Colourant Reference	Field No.	Locus	Description
YELLOW1 WHITE1	25.11.343	1086, Level VII	ib ('heart') pendant (McGovern 1985b: no.256). White glass with yellow and white impressed latitudinal bands.
BROWN1 BLUE1 WHITE2	25.11.393	1068, below steps, Level VIII	Ram's head pendant (McGovern 1985b: 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 (McGovern 1985b: 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	1068, north of steps, Level VII	Small mandrake fruit pendant (McGovern 1985b: no.169). Yellow frit with purple over glaze.
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 WHITE 7	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	1068, near steps Level VII	Reeds(?) pendant (McGovern 1985b: no.216). Blue glazed faience.

BL/GR2 BL/GR3	25.11.486	1068, near steps, Level VII	djed pendant (McGovern 1985b: 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	Spheroid bead. Blue transparent glass.
GRAY1 YELLOW3	26.9.171	1062, below south wall, Level VIII	Petal or leaf pendant (McGovern 1985b: no.210). White faience with yellow and grey overglazes.
BLUE5	27.9.451	1213A, Level VII	Hexagonal ellipsoid bead. Egyptian Blue frit.
BLUE6	27.9.472a	1221, Level VIII	Fluted spheroid bead. Egyptian Blue frit.
RED1	27.9.472c	1221, Level VIII	Disc bead. Red frit.
GR-IX2	27.10.39	1232, Level IX	Spheroid bead. Transparent green glass.
BLU-IX7	27.10.131	1232, Level IX	Cylindrical bead. Blue glass.
BLA-IX2 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 (McGovern 1985b: no.201). Blue-green glazed faience.
RED-IX2	28.8.50	1334, Level IX	Disc bead. Red glazed faience.
BLU-1X9	28.10.424c	1241, Level IX	Lenticular cylinder bead. Egyptian Blue frit.
B/GR-IX5	28.10.465	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	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.

Table 2 BAQ'AH VALLEY ANALYTICAL CORPUS: SILICATE SMALL ARTIFACTS

Colourant Reference	Field No.	Locus	Description
GRA-A2-1	A2.33	12, Cave A2	Disc bead. Gray faience or frit.
RED-A2-1	A2.56	17, Cave A2	Disc bead. Red glazed faience.
BRO-A2-1	A2.58	17, Cave A2	Cylindrical bead. Dark brown glazed frit.
YEL-A2-1	A2.61	17, Cave A2	Spheroid bead. White glass with yellow and white impressed eyes.
GRA-A2-2	A2.65	Balk trim, Cave A2	Disc bead. Gray glazed frit.
BLU-A2-1	A2.102	26, Cave A2	Fluted spheroid bead. Egyptian Blue glazed frit.
YEL-A2-2	A2.114	26, Cave A2	Fluted spheroid bead. Yellow glazed frit.
B/GR-A2-1	A2.117 A2.99	26, Cave A2	Fluted spheroid bead. Blue-green glazed faience.
YEL-A2-3	A2.137	27, Cave A2	Spheroid bead. White glass with gray, white, and yellow impressed crumbs.
B/GR-B3-2	B3.58	4, Cave B3	Disc bead. Blue-green glazed faience.
GRA-B3-3 BRO-B3-2	B3.81	8, Cave B3	Barrel bead with four fluted lobes. Dark brown glazed frit.
BLA-B3-1 GRA-B3-4	B3.103	8, Cave B3	Fluted spheroid bead with collars. Gray frit with black glaze.
BLU-B3-2	B3.150	11, Cave B3	Cylindrical bead. Egyptian Blue frit.
PUR-B3-1 BRO-B3-3	B3.182	3, Cave B3	Fluted cylindrical bead. Brown frit with purple glaze.
PUR-B3-2	B3.307	4, Cave B3	Spheroid bead. Purplish brown glazed frit.
BRO-B3-4	B3.311	4, Cave B3	Segmented bead - two spheroids. Brown glazed frit.
BRO-B3-5 WHI-B3-1	B3.358	14, Cave B3	Barrel bead. Brown glass with white impressed band.
PUR-B3-3	B3.359	14, Cave B3	Barrel bead. Purple and white variegated glass.
WHI-B3-2	B3.360	14, Cave B3	Barrel bead. Purple, silvery, yellow, and white variegated glass with silvery and white impressed bands.
YEL-B3-4	B3.363	8, Cave B3	Fluted bicone bead. Yellow frit.
GRA-A4-5	A4.2b	5, Cave A4	Spheroid bead. Gray frit.
RED-A4-2	A4.69	10, Cave A4	Spheroid bead with raised stratified eyes. Dark red glass with inlaid white silica eyes.
B/GR-A4-3	A4.96	9, Cave A4	Fluted spheroid. Egyptian Blue glazed frit.
RED-A4-3	A4.185a	9/13, Cave A4	Spherical bead. Dark red glass.

TABLE 3

PIXE DATA FOR BETH SHAN SPECIMENS (% by weight)

Colourant Reference	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CoO	NiO	CuO	ZnO	SnO	Sb_2O_5	PbO
YELLOW1	0.000	0.571	2.946	89.709	1.699	2.044	0.110	0.009	0.759	0.000	0.002	0.033	0.023	0.000	1.007	0.679
WHITE1	0.000	0.000	1.499	92.227	1.094	1.980	0.069	0.004	0.288	0.000	0.000	0.011	0.008	0.000	2.467	0.006
BROWN1	1.360	7.296	2.257	76.080	3.411	4.781	0.075	0.098	0.828	0.012	0.000	0.161	0.060	0.004	1.695	0.014
BLUE1	2.041	2.308	5.828	81.570	4.798	0.000	0.162	0.111	0.885	0.067	0.067	0.089	0.080	0.000	0.271	0.013
WHITE2	1.706	1.406	1.521	90.832	1.098	1.849	0.066	0.003	0.507	0.006	0.000	0.015	0.004	0.007	0.805	0.006
WHITE3	0.000	1.422	3.903	76.766	2.628	0.000	0.200	0.058	0.790	0.000	0.002	0.016	0.012	0.000	13.505	0.022
WHITE4	1.838	1.454	4.636	76.606	3.647	0.000	0.211	0.065	1.086	0.000	0.004	0.042	0.010	0.000	8.694	0.030
BROWN2	0.971	1.162	3.168	84.217	2.917	3.855	0.178	0.029	1.834	0.006	0.000	0.197	0.001	0.011	0.128	0.081
SILVER1	0.995	0.679	3.282	85.561	3.116	2.053	0.213	0.679	1.314	0.021	0.038	0.041	0.010	0.009	1.019	0.063
YELLOW2	0.000	2.683	1.712	81.304	0.555	2.363	0.000	0.025	0.385	0.000	0.000	0.087	0.228	0.000	2.284	8.300
PURPLE1	3.541	1.419	15.477	65.289	7.235	5.178	0.000	0.126	0.427	0.128	0.051	0.068	0.167	0.253	0.000	0.000
BROWN3	0.000	0.000	4.144	88.882	2.716	2.030	0.077	0.638	0.720	0.000	0.009	0.006	0.009	0.000	0.000	0.004
BROWN4	2.238	0.000	3.924	83.782	3.748	3.288	0.085	0.569	0.723	0.020	0.008	0.007	0.011	0.000	0.000	0.004
BLUE2	2.276	3.490	11.010	67.054	2.897	7.194	0.173	0.349	0.737	0.227	0.000	0.017	0.382	0.000	3.720	0.005
WHITE5	0.000	1.615	3.272	88.271	1.564	0.000	0.169	0.010	0.744	0.000	0.001	0.010	0.006	0.000	3.915	0.012
BROWN5	0.000	1.149	3.029	81.770	2.222	3.655	0.143	0.012	1.827	0.000	0.003	0.042	0.007	0.000	2.057	3.650
BL/GR1	0.000	1.028	3.337	86.456	2.734	2.291	0.157	0.000	2.058	0.000	0.018	0.173	0.004	0.071	1.008	0.017
SILVER2	0.000	1.245	2.069	92.353	1.361	1.372	0.063	0.000	0.690	0.000	0.001	0.019	0.010	0.000	0.000	0.009
BLACK1	9.717	4.710	1.028	72.671	3.831	6.787	0.064	0.019	0.505	0.006	0.000	0.025	0.003	0.000	0.000	0.005
WHITE6	0.000	1.017	5.078	79.987	3.433	5.486	0.165	0.006	0.722	0.000	0.001	0.013	0.002	0.000	3.440	0.006
WHITE7	0.000	0.682	6.077	81.089	3.355	3.253	0.151	0.007	0.700	0.000	0.001	0.006	0.003	0.034	4.096	0.004
WHITE8	0.000	0.627	3.636	82.391	2.566	3.253	0.141	0.013	0.546	0.010	0.001	0.009	0.18	0.000	5.662	0.002
PURPLE2	1.217	1.577	1.152	92.285	1.344	0.581	0.076	0.009	0.654	0.005	0.002	0.010	0.023	0.004	0.000	0.007
WHITE9	0.000	1.631	3.850	81.881	2.419	2.864	0.190	0.010	1.120	0.000	0.001	0.018	0.012	0.000	5.513	0.003
PURPLE3	0.608	1.307	1.031	94.788	1.038	0.264	0.058	0.008	0.609	0.009	0.000	0.014	0.002	0.002	0.000	0.008
BLUE3	0.000	0.859	4.654	85.804	3.171	1.356	0.092	0.145	0.489	0.000	0.068	2.060	0.143	0.000	0.000	0.017
BL/GR2	0.000	0.000	1.251	91.889	1.953	0.903	0.044	0.008	0.206	0.000	0.000	2.117	0.024	0.525	0.000	0.015
BL/GR3	1.865	0.626	1.138	88.991	1.163	0.704	0.027	0.005	0.186	0.000	0.006	4.034	0.031	0.000	0.000	0.029
SILVER3	0.000	1.705	4.705	83.330	3.205	4.257	0.107	0.038	0.887	0.000	0.000	0.008	0.006	0.000	0.000	0.002
SILVER4	0.000	0.000	4.234	91.454	1.945	1.166	0.091	0.068	0.485	0.000	0.001	0.011	0.008	0.000	0.000	0.002
WHITE10	0.000	0.994	3.290	86.789	1.659	3.671	0.162	0.017	0.737	0.000	0.001	0.007	0.011	0.000	2.421	0.002
BLUE4	9.641	3.812	1.217	74.446	3.233	5.524	0.041	0.032	0.339	0.000	0.002	0.678	0.000	0.000	0.000	0.001
GRAY1	0.000	0.809	1.752	91.668	1.841	1.650	0.041	0.232	0.286	0.295	0.142	0.094	0.184	0.000	0.000	0.000
YELLOW3	0.000	0.000	1.010	74.790	0.451	1.441	0.000	0.020	0.235	0.000	0.004	0.094	0.323	0.000	12.380	8.015
BLUE5	0.000	1.196	4.478	66.751	1.812	13.724	0.122	0.025	1.131	0.000	0.027	9.735	0.052	0.305	0.000	0.004
BLUE6	0.000	0.999	5.224	81.530	1.675	6.285	0.080	0.010	0.676	0.000	0.005	1.966	0.020	0.000	0.000	0.017
RED1	0.000	0.685	3.960	86.455	1.943	2.154	0.118	0.014	3.765	0.000	0.000	0.048	0.004	0.000	0.000	0.038
GR-IX2	8.403	2.978	1.220	78.794	2.876	4.535	0.025	0.033	0.255	0.000	0.001	0.002	0.003	0.000	0.000	0.001
BLU-IX7	7.352	2.231	0.979	68.834	1.585	8.648	0.073	0.016	0.361	0.000	0.000	0.953	0.007	0.000	8.245	0.002
BLA-IX2	4.344	6.356	2.970	70.666	6.586	7.306	0.093	0.049	0.757	0.007	0.004	0.033	0.012	0.089	0.000	0.010
WHI-IX11	0.000	0.000	7.224	80.712	4.197	3.456	0.170	0.004	0.434	0.000	0.001	0.011	0.006	0.000	3.050	0.002
BLU-IX8	5.710	4.023	7.750	67.401	1.995	9.541	0.089	0.351	0.503	0.110	0.000	0.021	0.189	0.000	1.830	0.003
BL/GR4	0.000	1.361	1.352	84.323	0.789	3.452	0.000	0.019	0.273	0.000	0.016	6.222	0.043	0.211	0.000	0.077
RED-IX2	0.000	0.000	1.509	86.913	3.047	3.414	0.119	0.019	4.043	0.000	0.000	0.069	0.042	0.000	0.000	0.012
BLU-IX9	0.000	2.377	7.438	59.926	2.471	20.299	0.252	0.037	2.966	0.000	0.011	1.045	0.000	0.634	0.000	0.000
B/GR-IX5	0.000	1.191	2.168	89.652	1.298	2.814	0.122	0.052	1.830	0.000	0.001	0.415	0.012	0.080	0.000	0.020
BLU-IX10	10.598	4.143	5.386	65.834	1.374	8.155	0.127	0.319	0.528	0.236	0.201	0.036	0.314	0.000	1.828	0.004
WHITE12	0.000	0.902	2.340	76.764	2.060	0.000	0.335	0.034	1.218	0.000	0.005	0.013	0.007	0.000	15.640	0.033
GRAY3	0.000	0.000	2.856	68.098	7.258	11.624	0.142	0.383	4.252	0.000	0.015	0.266	0.010	0.000	1.185	0.000
BROWN6	0.000	0.474	2.660	71.047	3.168	6.085	0.239	0.303	3.212	0.000	0.011	0.196	0.034	0.000	5.001	7.008
BLA-IX3	0.000	0.000	5.030	87.148	3.991	1.708	0.306	0.019	0.715	0.000	0.000	0.010	0.004	0.000	0.000	0.003
B/GR-IX6	0.000	0.000	2.785	85.665	3.764	2.317	0.140	0.019	2.428	0.000	0.010	0.312	0.004	0.000	1.265	0.029
BRO-IX7	0.000	0.000	6.420	79.061	5.247	4.580	0.200	0.009	1.207	0.000	0.000	0.009	0.003	0.000	1.391	1.275
WHI-IX13	0.000	0.000	5.581	76.423	5.158	5.523	0.353	0.036	0.829	0.000	0.000	0.013	0.006	0.000	3.568	0.049
MEAN	1.415	1.448	3.731	81.018	2.747	3.939	0.124	0.096	1.050	0.021	0.014	0.585	0.048	0.043	2.205	0.549

TABLE 4

PIXE DATA FOR BAQ'AH SPECIMENS (% by weight)

Colourant Reference	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CoO	NiO	CuO	ZnO	SnO	Sb_2O_5	PbO
GRA-A2-1	2.129	0.446	2.420	85.260	2.130	1.196	0.136	0.889	0.357	0.074	0.055	3.460	0.206	0.000	0.000	0.034
RED-A2-1	5.953	0.294	3.348	79.894	1.802	0.913	0.071	0.011	7.031	0.006	0.000	0.041	0.004	0.000	0.000	0.024
BRO-A2-1	0.747	0.280	0.806	94.391	0.184	0.393	0.048	1.734	0.957	0.002	0.007	0.278	0.014	0.071	0.000	0.000
YEL-A2-1	1.480	2.100	4.518	68.030	0.036	4.549	0.271	0.014	4.389	0.019	0.004	0.845	0.023	0.183	3.073	9.216
GRA-A2-2	1.592	2.169	6.185	79.777	0.390	4.189	0.231	0.711	1.292	0.200	0.100	1.829	0.210	0.000	0.000	0.046
BLU-A2-1	0.000	0.683	5.969	62.633	0.389	12.142	0.360	0.332	2.006	0.000	0.000	14.494	0.077	0.000	0.000	0.000
YEL-A2-2	0.697	0.488	0.681	87.557	0.021	0.283	0.050	0.003	0.833	0.016	0.001	0.013	0.003	0.102	2.896	6.182
B/GR-A2-1	2.003	0.727	2.941	87.666	0.528	2.318	0.232	0.019	1.468	0.002	0.001	1.824	0.008	0.037	0.000	0.042
YEL-A2-3	0.000	1.706	7.249	77.378	0.351	5.420	0.417	0.498	1.894	0.000	0.020	0.873	0.025	0.000	2.476	0.626
B/GR-B3-2	0.109	0.990	9.247	66.948	0.354	11.389	0.318	0.041	2.068	0.004	0.009	8.081	0.016	0.000	0.000	0.020
GRA-B3-3	1.039	0.271	2.329	85.990	0.121	1.037	0.131	4.658	1.845	0.136	0.049	1.440	0.107	0.237	0.167	0.022
BRO-B3-2	0.980	0.493	7.909	61.126	0.129	4.436	0.243	15.712	3.505	0.408	0.097	4.296	0.052	0.204	0.000	0.061
BLA-B3-1	0.702	0.660	2.878	84.174	0.106	2.640	0.168	4.361	1.937	1.269	0.314	0.465	0.070	0.062	0.000	0.018
GRA-B3-4	0.740	0.278	1.628	95.403	0.085	0.637	0.025	0.291	0.305	0.093	0.059	0.131	0.038	0.147	0.000	0.006
BLU-B3-2	0.000	0.475	1.265	58.852	0.320	17.822	0.165	0.030	0.954	0.000	0.000	17.660	0.023	1.203	0.020	0.000
PUR-B3-1	1.116	0.331	1.953	94.694	0.099	0.538	0.043	0.160	0.291	0.039	0.024	0.425	0.036	0.060	0.000	0.006
BRO-B3-3	0.774	0.486	6.442	73.042	0.306	5.302	0.280	5.851	2.353	1.226	0.197	2.966	0.064	0.028	0.000	0.067
PUR-B3-2	2.535	0.624	1.674	91.879	0.193	0.678	0.096	0.287	1.267	0.022	0.051	0.547	0.039	0.040	0.000	0.008
BRO-B3-4	0.392	0.175	0.513	96.943	0.079	0.197	0.043	1.231	0.242	0.001	0.004	0.026	0.008	0.078	0.000	0.002
BRO-B3-5	1.635	1.472	11.659	75.475	0.399	5.082	0.304	0.117	1.629	0.028	0.001	0.988	0.008	0.031	0.290	0.057
WHI-B3-1	1.583	0.409	8.857	72.598	0.268	0.000	0.184	0.035	1.230	0.027	0.000	0.654	0.004	0.000	13.633	0.066
PUR-B3-3	0.957	0.793	4.172	88.929	0.107	1.487	0.131	0.617	1.524	0.189	0.004	0.388	0.037	0.102	0.007	0.088
WHI-B3-2	0.557	0.351	3.768	71.565	0.017	0.000	0.000	0.054	2.211	0.077	0.000	1.384	0.029	0.060	19.109	0.050
YEL-B3-4	0.912	0.952	0.698	92.027	0.061	1.319	0.047	0.000	2.835	0.185	0.124	0.281	0.005	0.013	0.153	0.163
GRA-A4-5	2.944	0.517	1.809	92.643	0.277	0.207	0.077	0.186	0.613	0.187	0.232	0.062	0.080	0.000	0.000	0.010
RED-A4-2	6.486	0.208	1.187	50.653	2.737	1.502	0.198	0.073	34.912	0.727	0.009	0.138	0.020	0.042	0.248	0.025
B/GR-A4-3	0.126	0.167	0.480	77.226	0.342	5.613	0.420	0.000	1.260	0.000	0.000	12.432	0.005	0.624	0.102	0.040
RED-A4-3	0.663	0.493	0.566	44.677	0.383	2.861	0.359	0.012	47.960	0.416	0.012	0.026	0.020	0.925	0.000	0.012
MEAN	1.388	0.680	3.684	78.480	0.436	3.363	0.180	1.354	4.613	0.191	0.049	2.716	0.044	0.152	1.506	0.603