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The Beads from Tomb B10a B27 at Dinkha Tepe
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PATRICK E. McGOVERN, STUART J. FLEMING, AND CHARLES P. SWANN

Abstract

Among the rich finds from an early second millennium B.C. tomb at Dinkha Tepe in northwestern Iran was a collection of more than 140 beads, made of glass, frit, and semiprecious stones, which were probably worn as necklaces by the deceased. Fifty-eight of the beads were of glass and frit, and constitute one of the earliest, sizable groups of these man-made silicate materials ever found. The evident care that was taken in selecting and processing the raw materials and in working and firing the finished artifacts, as shown by consistent chemical and microstructural groupings, attests to a high level of expertise during an early stage in the history of glassmaking. The technological traditions displayed in the Dinkha group are comparable to those practiced later in the second millennium, during the floruit of silicate manufacture, but are less sophisticated in terms of their manufacture and range of colorants. Quite possibly, a number of small-scale, independent glass and frit workshops were in operation earlier in the second millennium in Azerbaijan or in the vicinity of other sites in northern Syria and Anatolia where similar silicate bead groups have been found. More analyses of glass and frit artifacts and raw material deposits are required before the full implications of the Dinkha Tepe corpus for the origins and development of glassmaking in the ancient Near East can be determined.

Tomb B10a B27 at Dinkha Tepe, Azerbaijan, in addition to many other exceptional artifacts,[1] yielded a large collection of glass, frit, and semiprecious stone beads. Moreover, since the tomb is dated ca. 1800–1600 B.C., according to the corrected radiocarbon determinations, the Dinkha beads constitute a very early occurrence of a sizable corpus of silicate materials that has important implications for the beginnings and subsequent development of glass and frit manufacture in the ancient Near East.

The excavated beads were clustered in the groups shown in figure 1, apart from an isolated long pear-shaped form (Di-66-573). Only the smaller subgroup of Di-66-582 was found in situ near the neck of a skeleton (ordered as shown on fig. 1), where it had presumably been worn as a necklace in life and death. Although the other groups, including the larger subgroup of Di-66-582, were not recovered in ordered sequences, it is reasonable to assume that these groups also comprised composite jewelry pieces, most likely necklaces.[2]

BEAD TYPOLOGY: DESCRIPTION AND COMPOSITE ARRANGEMENT

The beads fall into several main typological groups (table 1). For convenience and precise designation, the bead types are assigned a Beck classification number,[3] with similar shapes grouped together. As can be seen, the same shapes were made of several different materials—opaque blue glass, a white frit, a white frit with a surface covering of a dark-colored frit, and semiprecious stones (principally carnelian, but also hematite and agate). Only glass and semiprecious stones (in particular, agate) were used to make long-barrel, long truncated biconical, and pear-shaped forms. Frits were reserved for shorter forms—discs, oblates, and short barrels, cylinders, and truncated biconical forms. Carnelian was also used to make oblates and short barrels and truncated biconical beads. Five out of a total of seven blue glass beads examined are small oblates and short barrels.

The frit and glass beads have perforations with diameters of 0.1 cm, 0.2 cm, or 0.3 cm, and can be assigned to Beck Type VIa (holes less than a quarter but not more than half the diameter of the bead). Collars around the perforations on one end of some frit beads indicate that these holes had been made using a tool punch. The technique of making cylinder

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[1] See K.S. Rubinson, "A Mid-Second Millennium Tomb at Dinkha Tepe," in this issue, pp. 373–94.

[2] Three other groups of beads were recovered from the tomb, but were not available for examination: 1) Di-66-576, now in Teheran, an unspecified number of carnelian, agate, and "paste" beads; 2) Di-66-580, also in Teheran, four or five carnelian and "paste" beads; and 3) Di-66-560,UM 66-23-76, single examples of carnelian, agate, and shell beads. See Rubinson (supra n. 1) 390–94 for catalogue of the tomb

contents. "Paste" is an ambiguous, general term, used in the older archaeological literature to refer to a ceramic material—whether faience, frit, glass, pottery, etc. (see the "Glossary of Silicate Terms" in P.E. McGovern, "The Ultimate Attire: Jewelry from a Canaanite Temple at Beth Shan," *Expedition* 32 [1990] 16–23, and infra n. 7).

[3] H.C. Beck, "Classification and Nomenclature of Beads and Pendants," *Archaeologia* 77 (1927) 1–76.
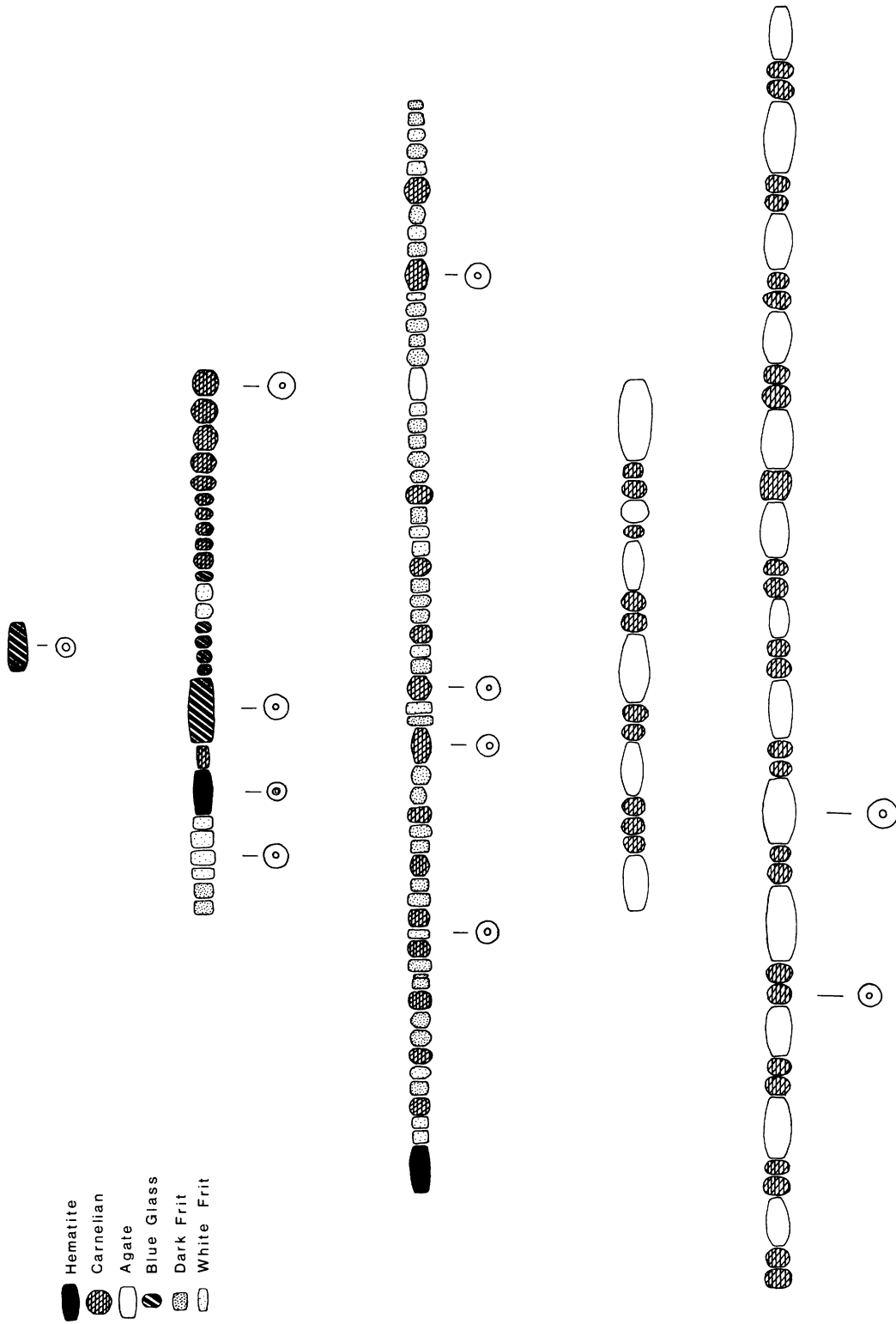
Fig. 1. Dinkha Tepe beads: top to bottom, Di-66-573, Di-66-575 (not ordered), Di-66-583 (not ordered), and Di-66-582 (divided into a smaller ordered subgroup and a larger non-ordered subgroup). Note that the sizes of the bead types—discs, oblates, cylinders, barrels, and truncated convex biconical forms—are quite comparable irrespective of material. Some size variation exists (e.g., a carnelian barrel bead in group Di-66-583 is relatively small, 0.7 × 0.4 cm), and two types occur only once—a carnelian lenticular bead (Di-66-582) and a frit segmented bead (Di-66-583) composed of a pair of separate cylinder disc beads that fused upon firing.

Table 1. Quantitative Analysis of Materials Used for Beads from Dinkha Tepe Tomb B10a B27

Sample by Bead Type	White Frit	Dark Frit (Surface)	Blue-Green Glass	Carnelian	Other Stones (Agate, Hematite)
Discs and Short Cylinder Beads (Beck I.A.1.b, I.A.2.b, and I.B.2.b)					
Di-66-575	4	2	—	—	—
Di-66-583	11	19	—	—	—
Oblate, Short Barrel, and Short Truncated Convex Biconical Beads (Beck I.B.1.a, I.B.1.b, and I.B.1.f)					
Di-66-575	2	—	5	10	—
Di-66-582	—	—	—	34	1
Di-66-583	2	10	—	12	—
Long Barrel and Long Truncated Convex Biconical Beads (Beck I.D.1.b, I.D.1.f, and I.D.2.b)					
Di-66-575	—	—	1	1	1
Di-66-582	—	—	—	—	18
Di-66-583	—	—	—	2	2
Long Piriform Bead (Beck I.D.1.g)					
Di-66-573	—	—	1	—	—
Lenticular Standard Barrel Bead (Beck IV.C.1.b)					
Di-66-582	—	—	—	1	—
Segmented Bead (2 cylinder discs) (Beck XVII.A.1.a)					
Di-66-583	—	1	—	—	—
Total	19 (14%)	32 (23%)	7 (5%)	60 (43%)	22 (16%)

For references to Beck types, see C. Beck, *Archaeologia* 77 (1927) 1–76.

disc beads by cutting a long cylinder into short sections was clearly used for some frit beads, since the outside perimeters of the beads have protuding edges. The glass beads were probably made by modeling viscous glass around an armature, since the bubbles are randomly distributed and there is no evidence of long cord or striae.[4] The long semiprecious stone beads were drilled conically from each end (Beck Type I, double cone); shorter beads of semiprecious stone were drilled conically from only one end (Beck Type III). The perforations are often off-center, and holes drilled from two ends often do not meet exactly, suggesting the use of a bow or pump drill.[5] Whereas the agate and hematite beads are well smoothed, a number of carnelian examples are rather roughly

shaped and finished. The agate beads were ground to exhibit the banding and zigzag patterning of the stone best.

Although the beads in Di-66-575 and Di-66-583 are arbitrarily arranged in figure 1, it is probable that the heavier and more prominent long barrels and cylinders were placed at the bottom of these jewelry pieces—"pendants" in the etymological sense of "hanging down."[6] The shorter beads might then have been arrayed to either side of the longer beads in an alternating sequence by shape, color, and/or size. Such an arrangement is analogous to the alternating pairs of carnelian oblates/short barrels and agate long-barrel beads on necklace Di-66-582, found in situ. The color scheme of each necklace, whether achieved with

[4] No metal or organic material from an armature, however, was noted inside any perforation. Silicates were examined under low-power magnification (up to 180×), using a stereozoom microscope with fiber optic lighting. Glass and frit can be adequately distinguished at this level, the extent of fusion and weathering assessed, and inclusional and other microstructural features characterized. Although prepared

sections of the beads could not be made, the interior matrix was visible in abraded and heavily weathered examples.

[5] The bow drill is especially well attested in the ancient Near East, e.g., Egypt: A. Wilkinson, *Ancient Egyptian Jewellery* (London 1971) 3, fig. 1.

[6] P.E. McGovern, *Late Bronze Palestinian Pendants: Innovation in a Cosmopolitan Age* (Sheffield 1985) ch. 1.

frits, glasses, or semiprecious stones, is red, white, gray/purple/black, and, in one instance (Di-66-583), also blue.

SILICATES: MICROSTRUCTURE AND COMPOSITION

The silicate materials—glass and frit—used in making 58 of the Dinkha beads are particularly significant. They constitute one of the earliest substantive collections of these man-made ("synthetic") materials, which have silica (sand) as their main constituent. The addition of an alkali salt, such as sodium carbonate or potash in the form of plant ash, enables silica to be fluxed at relatively low temperatures (ca. 600–700° C) to form an amorphous, "fused" silicate structure—glass. Pure silica melts at 1723° C, well beyond the pyrotechnological capabilities of the ancient Near East. Yet, a high percentage of silica, mixed with colorant and alkali, can be made into a durable material—frit—by firing up to 900–1000° C, comparable to the temperature range of well-fired second-millennium B.C. pottery. Sintering between individual particles is observed in a frit, but a well-defined glaze, a fused glassy layer on the surface where temperatures are highest, is not found.[7]

The glasses in the Dinkha groups have spherical bubbles, averaging about 1 mm in diameter (ranging up to 2 mm), distributed throughout the matrix. The frequency of bubbles is quite variable; it is very low in the long barrel bead (Di-66-575). The beads are weathered to differing extents. The blue coloration has been totally leached out from the surface (to a depth of about 1.5 mm) of the long barrel bead, and hydration layers are flaking off from it. The piriform bead (Di-66-573) and the small oblates and short barrels (Di-66-575) are better preserved, but have large white patches where the cupric ions have dissolved out. The only nearly intact bead is one small oblate in group Di-66-575.

The white frit (fig. 2) is composed almost exclusively of silica particles, with diameters of approximately 1.5 mm, ranging to 5 mm. Vitrification ("wetting" or

sintering) is evident between interior particles, and increases near the surface where particles had been exposed to higher temperatures. Traces of a surface glaze can be seen on a few examples, but it is highly weathered.

The dark frit (fig. 2) has an interior core of white frit, which appears to be exactly comparable to the microstructure of the white frit beads. It differs from the latter in having a surface layer of a dark frit, which is composed of quartz particles *and* black particles. The black particles are an order of magnitude smaller (0.2–0.4 mm) than the quartz particles, which have the same size distribution (1–2 mm) as the white frit. Depending on the amount of dark frit originally present in the frit, or that remains after weathering, the coloration is generally light to dark gray or black. A few dark frit examples have a purplish or reddish hue, due to the presence of a higher percentage of purplish- or reddish-colored quartz particles. Patches of surface "glaze" in which the surface dark frit and quartz particles have fused together to a limited extent were also noted on several beads.

White Frit

The silicate materials were chemically analyzed by proton-induced X-ray emission (PIXE) spectrometry, a highly efficient technique that non-destructively measures the concentrations of 21 elements.[8] As can be seen in tables 2a–b, the white frits (samples a–d) have very pure silica compositions. Soda and potassium oxide contents are much less than would be expected if either or both were added as fluxing agents, but these low atomic weight elements are easily leached out. The iron and copper oxide contents are quite varied, most probably a result of natural variability in the silica source, workshop contamination, and/or deliberate selection of raw materials.[9] Heavy metals, which most often contribute to coloration,[10] are at near-negligible levels.

Dark Frit

The dark frit surfaces (samples e and f), which cover white frit cores, are characterized by much

[7] According to modern scientific usage (see C. Parmelee, *Ceramic Glazes*, Chicago 1948), frits are pre-fused silicate materials incorporated into a glaze/glass batch mixture or used separately. Glass is often treated separately from frit in the literature on ancient glass. Both materials, however, are found together in the earliest archaeological contexts that have yielded sizable groups of glass artifacts. This suggests that the origins and subsequent development of glassmaking are related to frit manufacture, and justifies treating the two silicate materials in the same article.

[8] For experimental details, see S.J. Fleming and C.P. Swann, "Color Additives and Trace Elements in Ancient Glasses: Specialized Studies Using PIXE Spectrometry," *Nuclear Instruments and Methods in Physics Research* B22 (1987) 411–18; a recent paper of specific relevance to the Dinkha

silicates is C.P. Swann, P.E. McGovern, and S.J. Fleming, "Colorants in Glasses from Ancient Syro-Palestine: Specialized Studies Using PIXE Spectrometry," *Nuclear Instruments and Methods in Physics Research* B40/41 (1989) 615–19. Scanning over a 0.4 mm² area gives a representative, average chemical composition for the heterogeneous frits. Care was taken to analyze relatively intact areas of glass. As glass is a more homogeneous material, the analyses were conveniently reduced to as little as 0.04 mm² (S.J. Fleming and C.P. Swann, "The Bartol PIXE Microprobe Facility: Recent Applications in Archaeology," *Nuclear Instruments and Methods in Physics Research* B30 [1988] 444–53).

[9] C.R. Bamford, *Colour Generation and Control in Glass* (Amsterdam 1977).

[10] Weathering effects, in which frit particles with varying

Fig. 2. Close-up view (approximately 3× magnification) of eight beads in group Di-66-575. From left to right, a carnelian oblate bead, two black frit short cylinders, four white frit short cylinders, and a hematite long barrel. The third white frit bead from the left (sample a in tables 2a–b) has a broken edge, in which a matrix of variously sized quartz particles is visible; the white frit bead to its right is sample b. The black frit beads exhibit varying degrees of surface particle fusion and visibility of the underlying white frit cores.

higher levels of copper (4.6% and 20.3%, respectively) and manganese (31.1% and 4.4%, respectively) oxides than the white frits (samples a–d). Because the primary difference between the white and dark frits is the presence of the small, dark particles in the latter, these particles must be largely responsible for the increased amounts of the major and minor heavy elements. In sufficient quantity and in a variety of admixtures, these colorants can effectively block out all light, and thus appear black. Depending upon whether manganese, copper, iron, or another metal predominates in the black frit and/or whether these metals have gone into ionic solution,[11] a more specific coloration, such as the reddish or purplish hue noted on some beads, will be the result. Since high and low amounts of manganese and copper oxides are reversed in samples e and f, possibly a manganese ingredient was mixed with a copper ingredient in making the dark-colored frit. Depending on the relative amounts of ingredients in the original batch and how well they were mixed, frit particles might be relatively more copper- or manganese-rich. Alternatively, differing amounts of the two metals might be

due to variability in a single ore body, or possibly weathering effects.

The amounts of some of the other oxides at the minor and trace level also appear to be elevated in the dark frits (see table 2b), but correlations with manganese and copper contents cannot be securely made because of the small number of samples. With this proviso, it will be observed that iron, titanium, and potassium are elevated to approximately the same degree (a factor of 5 or 6) in the two dark frit samples, and, to lesser and varying extents, lead, zinc, and sulfur.[12] The comparable increases in iron, titanium, and potassium suggest that they are associated in the raw materials. The increase in the amounts of nickel and molybdenum oxides in sample e is possibly correlated with this frit's very high manganese content.

Blue Glass

The opaque blue glass samples (g–i) are colored by cupric ions,[13] and the copper oxide (ranging from 2.94% to 9.23%, as the oxide) appears to be associated with somewhat elevated lead, nickel, and zinc oxides. The glass is of a soda-lime-silicate composition, with

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amounts of metal oxides are concentrated in pores, are also a possibility.

[11] Note that cupric (Cu^{+2}) and manganic (Mn^{+3}) ions in soda-lime-silica glass have absorption maxima at 7800 Å and 4900 Å in the visible spectrum, which impart blue-green and purple colorations, respectively (Bamford [supra n. 9] 48–51, figs. 2.6, 2.7).

[12] The amount of cobalt oxide (average of ≤0.25%) in the dark frits might appear to exceed that in the white frits (average of ≤0.10%). The figures cited, however, are experimental detection limits, and it is not known whether the white and dark frits are compositionally similar or dissimilar in their cobalt content.

[13] Bamford (supra n. 9) 48–50.

Table 2a. Compositional Data for Dinkha Tepe Silicates: Primary Constituents

Sample by	Primary Constituents (each as % oxide, by weight)						
Material	SiO_2	Na_2O	K_2O	MgO	Al_2O_3	CaO	Fe_2O_3
White frit:							
a (Di-66-575)	96.9	≤0.60	0.15	≤0.28	1.00	≤0.10	0.31
b (Di-66-575)	90.9	≤1.50	1.00	≤0.66	1.80	0.87	1.70
c (Di-66-583)	94.7	≤0.98	0.75	0.47	1.70	0.19	0.24
d (Di-66-583)	90.5	≤1.10	1.10	≤0.59	1.90	0.88	0.84
Dark frit:							
e (Di-66-583)	41.1	≤1.20	2.80	0.87	2.30	3.30	3.80
f (Di-66-583)	51.3	≤1.70	5.20	≤0.73	2.70	3.80	5.20
Blue glass:							
g (Di-66-573)	79.1	≤1.70	0.91	≤0.62	0.83	2.30	0.27
h (Di-66-575)	66.8	9.60	3.60	5.50	1.10	4.10	1.00
i (Di-66-575)	60.2	7.40	2.70	3.10	0.96	9.30	2.70

Values are determined by PIXE spectrometry.
Experimental detection limits are indicated by ≤.

a high potassium oxide-magnesia content (table 2a), typical of second-millennium B.C. Near Eastern glasses.[14] The large amount (8.2%) of antimony in sample i and the smaller, yet significant amount (0.24%) in sample h are probably not accidental, since antimony was commonly used as an opacifier later in the second millennium B.C.[15] The fact that neither the tin nor the arsenic oxide levels are significantly elevated in these copper-rich glasses would seem to exclude scrap copper alloys being used as a colorant.

IMPLICATIONS FOR THE EARLY HISTORY OF GLASSMAKING

Isolated beads of glassy materials have been found in late third millennium B.C. contexts in Lower Mesopotamia and Egypt.[16] They are most plausibly understood as by-products of faience/stone glazing or metal smelting, in which a glass mass or slag was worked into small artifacts.[17]

Somewhat larger groups of glass beads are reported from the first half of the second millennium B.C.— particularly in Anatolia (Troy, Bŏgazkŏy, and Ali-

shar), Syria (Alalakh), and Iran (Geoy Tepe)—but they are poorly dated and characterized.[18] The Geoy Tepe glass is of special interest, since this site is very close to Dinkha Tepe, west of Lake Urmia. As many as 24 blue glass disc and radially grooved oblate bead types were found in Grave C,[19] and at least one blue glass disc bead in Tomb I,[20] both contexts belonging to Geoy C–D.[21] Other beads from these tombs appear to have been made of white and dark frits, carnelian, and agate, as well as other materials (gold, clay, steatite, etc.). Disc, oblate, and short- and long-barrel and cylinder types predominate (as for the Tomb B10a B27 beads at Dinkha). Crawford notes that the agate long-barrel beads are "excellently finished," whereas carnelian oblates are "almost like unfinished rough-outs ... possibly they represent local workmanship."[22] The relative numbers of differently sized, shaped, and colored beads, and therefore presumably their composite arrangement as necklaces, are also comparable to those of the Dinkha Tepe groups.

Spectrophotometric analysis of three blue glass disc beads from the Geoy Grave C group[23] identified co-

[14] E.V. Sayre and R.W. Smith, "Analytical Studies of Ancient Egyptian Glass," in A. Bishay ed., Recent Advances in Science and Technology of Materials 3 (London 1974) 47–70.

[15] E.V. Sayre, "The Intentional Use of Antimony and Manganese in Ancient Glasses," in F.R. Matson and G.E. Rindone eds., Advances in Glass Technology, Pt. 2 (New York 1963) 262–82.

[16] P.R.S. Moorey, Materials and Manufacture in Ancient Mesopotamia (Oxford 1985) 194–99.

[17] R.H. Brill, "Ancient Glass," Scientific American 209 (1963) 120–31.

[18] Moorey (supra n. 16). A more thorough search through collections of excavated jewelry dating to the early second millennium B.C. from these sites and others may well "uncover" more glass and frit beads. If sufficiently large silicate groups from a number of sites are microstructurally and chemically characterized, then inferences about the origins

and subsequent history of glassmaking in the ancient Near East will be more securely based.

[19] T. Burton Brown, Excavations in Azarbaijan, 1948 (London 1951) 127–30, cf. fig. 28.

[20] H.C. Crawford, "Geoy Tepe 1903: Material in the Collection of the Fitzwilliam Museum, Cambridge," IrAnt 11 (1975) 12–13, 23, pl. 1, no. I.18.

[21] The dating of levels C and D at Geoy is debatable: cf. C. [Kramer] Hamlin, The Habur Ware Ceramic Assemblage of Northern Mesopotamia: An Analysis of Its Distribution (Diss. Univ. of Pennsylvania 1971) 141; Crawford (supra n. 20) 18–22; M. Edwards, "'Urmia Ware' and Its Distribution in North-Western Iran in the Second Millennium B.C.: A Review of the Results of Excavations and Surveys," Iran 24 (1986) 57–62.

[22] Crawford (supra n. 20) 13.

[23] Burton Brown, supra n. 19.

Table 2b. Compositional Data for Dinkha Tepe Silicates: Other Constituents

Sample by Material	Other Constituents (each as % oxide, by weight)													
	SO₃	TiO₂	MnO	CoO	NiO	CuO	ZnO	As₂O₃	SrO	MoO	Ag₂O	SnO	Sb₂O₅	PbO
White frit:														
a (Di-66-575)	0.07	0.021	≤0.003	≤0.018	≤0.006	≤0.058	≤0.031	≤0.004	0.004	≤0.013	≤0.030	≤0.051	≤0.008	≤0.005
b (Di-66-575)	0.71	0.092	0.028	≤0.330	≤0.010	0.550	0.064	≤0.011	0.018	≤0.013	≤0.012	≤0.040	≤0.047	0.010
c (Di-66-583)	0.27	0.009	0.012	≤0.013	≤0.005	0.200	≤0.008	0.002	0.005	≤0.012	≤0.022	≤0.048	≤0.051	0.004
d (Di-66-583)	0.93	0.034	0.032	≤0.033	≤0.015	0.560	≤0.035	≤0.004	0.016	≤0.029	≤0.070	≤0.160	≤0.170	≤0.010
Dark frit:														
e (Di-66-583)	4.40	0.200	31.100	≤0.210	0.980	4.600	0.180	0.036	≤0.086	0.950	≤0.012	≤0.027	≤0.037	0.018
f (Di-66-583)	1.40	0.290	4.400	≤0.290	≤0.013	20.300	0.970	≤0.012	0.060	≤0.009	≤0.009	≤0.013	≤0.013	0.036
Blue glass:														
g (Di-66-573)	1.70	0.014	≤0.059	≤0.013	≤0.018	9.200	0.021	0.010	0.010	≤0.014	≤0.009	≤0.027	≤0.030	0.026
h (Di-66-575)	0.88	0.057	0.060	≤0.030	0.056	5.400	0.046	0.015	0.130	≤0.015	≤0.026	≤0.044	0.240	0.011
i (Di-66-575)	0.23	0.360	0.058	≤0.067	0.037	2.900	0.130	0.035	0.190	≤0.023	≤0.040	≤0.093	8.200	0.071

Values are determined by PIXE spectrometry.
Experimental detection limits are indicated by ≤.

balt as the principal colorant. The elemental concentration of cobalt is not given nor are any other elements reported, so that the chemical comparability of the Geoy and Dinkha blue glasses unfortunately cannot be assessed. Yet at least macroscopically, on the basis of size, shape, and "dark blue" coloration, the Geoy glass beads would appear to be quite comparable to the Dinkha beads.

During the period between ca. 1500 and 1200 B.C., many more and much larger groups of glass and frit artifacts (small artifacts and vessels) are attested at sites throughout the ancient Near East.[24] The different chemical compositions of the glasses from sites such as Tell al-Rimah, Nuzi, Nippur, and in the Baq'ah Valley demonstrate that they were largely produced by well-developed, local industries at or near each site.[25] The similarity of industrial techniques employed in preparing and working the glasses, frits, and faiences suggests that the industries shared a common technological tradition. Yet, each industry appears to have exploited the raw materials, especially colorants and opacifiers, that were locally available. Black glasses and frits at each site, for example, might be colored by copper, manganese, and/or cobalt in combination, but these metals are not associated with different minor or trace elements.

Silicate Technological Traditions of the Second Millennium B.C.

Textual evidence for glassmaking[26] dates back to the second half of the second millennium. Because of a complex historical development and specialized, unique vocabulary, it is debatable whether this literary tradition derives from a still earlier period and whether the beginnings of glassmaking are to be placed in northern Syria.[27]

Archaeologically, however, the Dinkha Tepe beads enable silicate technological traditions to be traced back into the early part of the second millennium B.C., independent of any textual evidence. Similarities *and* differences between the well-studied silicate materials from the site of Nuzi[28] in northern Mesopotamia, dating to the 15th–14th century B.C., and the Dinkha Tepe collection illustrate how these traditions might have developed. For example, the silica particles of the Nuzi white and black frits are much smaller (≤0.070 mm) than the Dinkha frits (approximately 1.5 mm). Whereas the Nuzi white frit appears to be sintered to about the same extent as the Dinkha white frit, the black frit at Nuzi has a larger glassy volume fraction. A similar process of calcining the frit, grinding, wetting and shaping, and firing it was probably used at both sites, but the Nuzi frits were

[24] Moorey (supra n. 16) 201–206.

[25] A.M. Pollard and P.R.S. Moorey, "Some Analyses of Middle Assyrian Faience and Related Materials from Tell al-Rimah in Iraq," *Archaeometry* 14 (1982) 45–50. P.B. Vandiver, "Mid-Second Millennium B.C. Soda-Lime-Silicate Technology at Nuzi (Iraq)," in T.A. Wertime and S.F. Wertime eds., *Early Pyrotechnology: The Evolution of the First Fire-Using Industries* (Washington, D.C. 1972) 73–92; Vandiver, "Glass Technology at the Mid-Second-Millennium B.C. Hurrian Site of Nuzi," *JGS* 25 (1983) 239–47. R.E.M. Hedges, "Pre-Islamic Glazes in Mesopotamia—Nippur," *Ar-*

chaeometry 18 (1976) 209–11. P.E. McGovern, *The Late Bronze and Early Iron Ages of Central Transjordan: The Baq'ah Valley Project. 1977–1981* (Philadelphia 1986) 202–42.

[26] A.L. Oppenheim, R.H. Brill, D. Barag, and A. von Saldern, *Glass and Glassmaking in Ancient Mesopotamia* (Corning 1970).

[27] Cf. Moorey (supra n. 16) 224–29, and A.L. Oppenheim, "A Note on Research in Mesopotamian Glass," *JGS* 15 (1974) 9–11.

[28] Vandiver, supra n. 25.

better ground and sometimes better fired. Compositionally, though, the frits at the two sites appear to be quite different. According to semi-quantitative analyses, the Nuzi black frits are colored principally by iron, and the white frits have a calcite fraction that is lacking in the Dinkha white frits. Red, blue, and yellow frits also occur at Nuzi, but are unattested at Dinkha Tepe.

Unlike the Dinkha blue glasses, with numerous and large bubbles, the Nuzi glass had only a few small (0.005–0.01 mm diameter) bubbles, indicating that it was better mixed and/or fired at higher temperatures. Microprobe analyses indicate that the translucent and opaque Nuzi blue glass was of a high potassium oxide-magnesia composition[29] and colored by cupric ions, as was the Dinkha glass. The copper content of the Nuzi blue glass, however, appears to be lower than that of the Dinkha glass, and is not reported to be associated with elevated levels of nickel, zinc, lead, and/or antimony. White, red, yellow, brown, and black glasses were also recovered at Nuzi, but not at Dinkha Tepe. A metal armature, with a parting layer, had been used to produce some of the Nuzi beads, in which threads of viscous glass were wound around the armature; the Dinkha examples, on the other hand, were probably freely modeled, possibly on an armature, since no threads are visible.

Dinkha Tepe glasses and frits would therefore appear to have employed a more limited range of colorants and less sophisticated manufacturing techniques than silicates produced after 1500 B.C. The differences between the Dinkha and Nuzi silicates are what one might expect if the Dinkha materials represent an earlier stage in the same or a closely affiliated technological tradition, leading to the emergence of discrete industries in many parts of the ancient Near East.

A Local Azerbaijani Silicate Industry?

The question whether the Dinkha Tepe silicate beads are products of a local Azerbaijani silicate industry cannot yet be answered. Even if a larger data base existed for the early second millennium B.C. silicates, nine chemical analyses of Dinkha glasses and frits do not provide an adequate statistical basis for establishing whether the metal colorants (copper and

manganese) are meaningfully correlated with elevated levels of other minor and trace elements (e.g., iron, titanium, lead, nickel, molybdenum, and sulfur). The composition of copper sulfide ore bodies in Azerbaijan and the Alborz Mountains, which are accompanied by iron, lead, nickel, zinc, manganese, cobalt, and molybdenum,[30] is not inconsistent with the colorant profiles of the Dinkha frits and glasses. But, lacking detailed chemical analyses of the heterogeneous ore deposits and recognizing that there might be considerable metal partitioning during the smelting and fritting processes,[31] the origin and place of manufacture of the Dinkha beads cannot yet be established.

If the Azerbaijani region of northwestern Iran were part of the Old Assyrian trade network, which included northern Syria and Anatolia,[32] as a staging and production area for various materials such as copper and tin,[33] this might explain why similar groups of glass beads have been found at a number of early second millennium B.C. sites throughout the trading region. Whether only one area supplied its trade partners is uncertain. Analogously to later developments, a number of small-scale, independent glass and frit workshops might well have been in operation in several places. To account for the relatively large groups of silicate beads found in Dinkha Tepe and Geoy Tepe, a silicate industry might already have been established somewhere in Azerbaijan. Definitive evidence for this hypothesis, however, must await more technical studies of silicates from this poorly understood period near the beginnings of glassmaking in the ancient Near East.

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[29] Sayre and Smith, supra n. 14.

[30] D. Bazin and H. Hubner, *Copper Deposits in Iran* (Teheran 1969) 19–37, tables 4 and 5.

[31] R.F. Tylecote, H.A. Ghaznavi, and P.J. Boydell, "Partitioning of Trace Elements between the Ores, Fluxes, Slags and Metal during Smelting of Copper," *JAS* 4 (1977) 305–33; P.T. Craddock and A.R. Giumlia-Mait, "Problems and Possibilities for Provenancing Bronzes by Chemical Composition, with Special Reference to Western Asia and the

Mediterranean in the Early Iron Age," in J. Curtis ed., *Bronzeworking Centres of Western Asia c. 1000–539 B.C.* (London 1988) 317–27.

[32] Rubinson (supra n. 1) 389–90; M.T. Larsen, "Commercial Networks in the Ancient Near East," in M. Rowlands et al. eds., *Centre and Periphery in the Ancient World* (Cambridge 1987) 47–56; Moorey (supra n. 16) 199.

[33] See Rubinson (supra n. 1) 389–90; Crawford (supra n. 20) 22.