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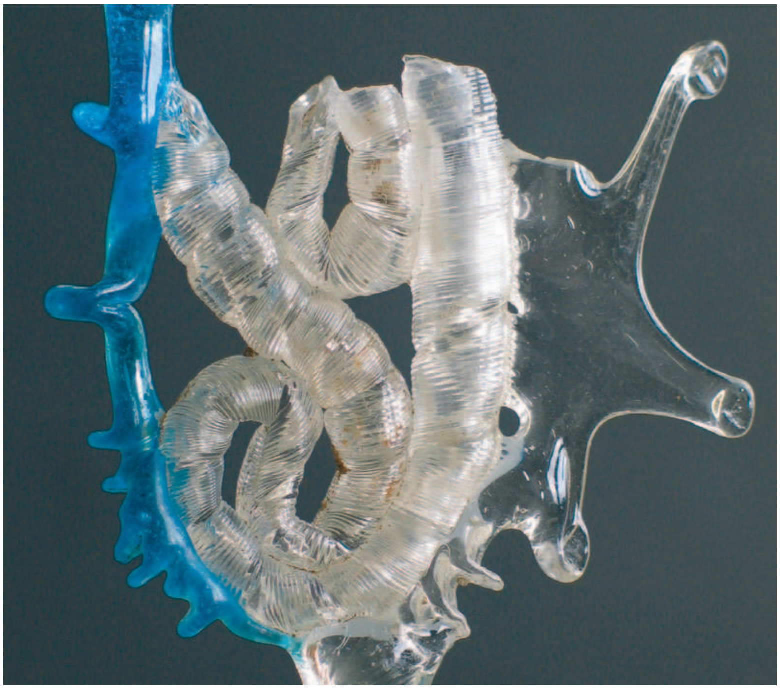

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AN ARCHAEOLOGICAL AND SCIENTIFIC STUDY OF MYCENAEAN GLASS FROM ELATEIA-ALONAKI, GREECE

Kalliopi Nikita*, Julian Henderson and Georg Nightingale

INTRODUCTION

This work presents and discusses the results of the archaeological and scientific study of glass jewellery from the Mycenaean chamber tomb cemetery at Elateia-Alonaki (Deger-Jalkotzy 1990-1991; Nightingale 1996; Nightingale 2003). Elateia is situated in the ancient landscape of Phocis in the upper Kephissos valley on a crossing of major trade routes in the northern periphery of the important Mycenaean states of Boeotia. The cemetery of Elateia-Alonaki was used from the middle of the 15th century BC (LH IIB/IIIA 1), and it survived the total breakdown of the Mycenaean palace states of about 1190/1180 BC. The highest frequency of use occurred in the post-palatial period from the 12th to the 10th centuries BC (LH IIIC, Submycenaean, Protogeometric Period). The latest burials happened in the 8th century BC. Among the small finds were many different types of simple Mycenaean glass and faience beads (including two trail-decorated glass beads) and glass relief beads. Most of the glass beads are heavily corroded. The well-preserved examples are mostly annular shaped beads and one horned stratified eye-bead (Nightingale 1996; Nightingale 2003).

THE MYCENAEAN GLASS INDUSTRY

The abundance, diversity and standardisation of the Mycenaean glass jewellery and its wide distribution all over the Mycenaean world, show that a thriving glass industry existed during the Mycenaean palatial period, *c.* 1450-1200 BC (Nightingale 2000; Nightingale 2008; Nikita 2003a, with further references). What set the Mycenaean glass industry apart from its contemporaneous glass-producing centres in the Mediterranean and the Near East was the nearly exclusive manufacture of glass jewellery and ornaments, mostly of a dark blue, light blue or turquoise colour. The accepted interpretation so far has been that the Mycenaean glass industry involved secondary glass production only (Nightingale 2000; Nightingale 2008; Nikita 2003a, 23-24; Panagiotaki *et al.* 2005). The argument has been based on the lack of industrial remains of glass-making in the Aegean, the principal manufacture of minor objects (Nikita 2003a), and the limited number of chemical analyses of well-dated Mycenaean glass (Brill 1999; Nikita 2003b; Panagiotaki *et al.* 2005; Tite *et al.* 2005). It has been suggested that ready-made glass was obtained from an Eastern glass-producing centre, which was then remelted. The discovery of glass ingots on the Late Bronze Age shipwreck of Uluburun, close to the Lycian coast, has corroborated these assumptions.

THE SAMPLES

Eighty-one samples from simple and relief glass beads were made available. Most of the beads and relief plaques sampled are of a monochrome translucent dark blue, light blue or turquoise colour. One translucent purple and three transparent colourless glass beads were examined. One opaque turquoise bead was also sampled as well as a bi-chrome horned eye glass bead with a translucent turquoise core and stratified eyes of opaque white glass. The analyzed glass dates from the beginning of the Late Helladic IIIA period (about 1425/1390 BC) to the Early Protogeometric period (about 1000/950 BC).

ANALYTICAL TECHNIQUE

Electron probe microanalysis is a microdestructive technique for which samples as small as 0.5 mm in length are required. Samples were mounted in epoxy resin and polished flat to expose an un-weathered section. A thin carbon coating was applied to the polished sample surface in order to prevent localized charging and any resulting distortion and deflection of the electron beam. A Cameca SX50 electron microprobe was operated at 15 kV and 20 nA, with a defocused 50 µm diameter beam. Results were calibrated using Corning glass standards and geological standards. Quantitative analyses were corrected using a "ZAF" routine.

ANALYTICAL RESULTS

The results from 81 glasses (Table 1) fall into the two main compositional categories of the Late Bronze Age owing to differences in their alkali contents and their associated impurities, namely the plant ash or HMG glasses (Sayre and Smith 1961, 1824-1826, table I, fig. 1), and the mixed-alkali or LMHK glasses (Henderson 1988a; Henderson 1988b, 77-91; Henderson 1989, 40-44).

Plant ash glasses (HMG)

The first major group of glasses (n = 63) (Table 1**)**, is characterized by elevated levels of potassium oxide (0.18 - 1.44 wt%) and the high levels of magnesia contents (0.37 - 5.49 wt%). Soda in these glasses was found at high levels (13.44 - 20.23 wt%). Ashes of halophytic plants were used as a fluxing medium (Henderson 1985, 271-276; Barkoudah and Henderson 2006; Nikita and Henderson 2006, with further references; Tite *et al.* 2005).

A plot of potassium oxide versus magnesia for glasses from Mesopotamia, Egypt, the Uluburun shipwreck, Mycenaean Thebes and Elateia shows that Tell Brak and Nuzi glasses are much richer in potassium oxide whilst most of the Mycenaean glasses tend to have the lowest contents (Fig. 1). Therefore, plant ashes with different chemical compositions (resulting from a range of potential factors) were used to make them or it may have resulted from a two-batch plant ash recipe (Lilyquist and Brill 1995, 42-43, nos. 94 and 57, figs. 52-54; Rehren 2001, 486-487; Henderson and Barkoudah 2006, 303 and 320-321). Nine non-cobalt glasses from Elateia, which contain higher magnesia (4.36 - 5.49 wt%) with associated higher potassium oxide levels, fall within the plotted data for Mesopotamian glasses. Either direct importation of this glass as finished beads or re-melting of imported ready-made glass from Mesopotamia can be suggested.

Mixed-alkali glasses (LMHK)

The second set of glasses (n = 18) is of a mixed-alkali type due to the presence of high levels of potassium oxide (6.01 - 11.53 wt%) and low magnesia contents (0.54 - 1.10 wt%). Soda was found at lower levels (5.64 - 10.10 wt%). High levels of silica (72.12 - 76.36 wt%) result, in some cases, from unreacted silica crystals. Levels of calcium oxide are very low (1.25 - 3.20 wt%; Table 1).

The alkali used for the LMHK glasses is distinctly different from that found in the HMG

Table 1. Glass analyses from Elateia-Alonaki. Mean values for the major components, colorants and their associated impurities in all HMG and LMHK glass (all concentrations in wt%).

	SiO_2	Na_2O	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5					
HMG (n=63)	66.77	17.12	1.35	6.09	3.05	0.59	2.02	0.15					
LMHK (n=18)	74.30	6.23	9.10	2.26	0.85	1.05	2.40	0.22					
	SiO_2	**Na_2O**	**K_2O**	**CaO**	**MgO**	**Fe_2O_3**	**Al_2O_3**	**P_2O_5**	**CoO**	**CuO**	**MnO**	**NiO**	**As_2O_5**
HMG dark blue (n=13)	67.68	17.43	1.03	6.02	2.69	0.61	2.17	0.15	0.10	0.16	0.17	0.07	0.01
HMG dark blue (n=13)	74.51	5.88	9.02	2.42	0.88	1.19	2.66	0.24	0.11	1.37	0.02	0.26	0.03

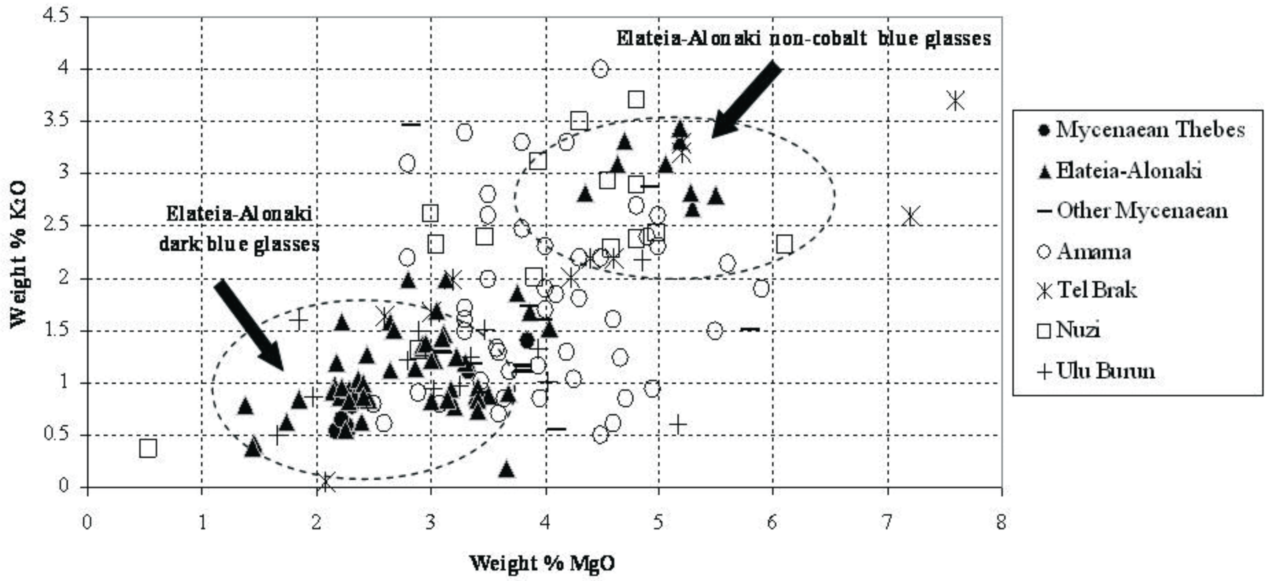

Fig. 1. A plot of K_2O versus MgO in plant ash glasses of all colours from Elateia-Alonaki, Mycenaean Thebes, Egypt, Mesopotamia and Uluburun.

glasses. Brill (1992, 17-18) has suggested that the glassmaking flux was some form of manurial soil or efflorescent salts from latrines that were rich in saltpetre (KNO_3) and salts such as niter ($NaNO_3$). The relative calcium oxide and phosphorus pentoxide contents in Elateia LMHK glasses differentiate them from the Thasian (Henderson 1992) and Italian vitreous materials dating to the 11th - 9th centuries BC (Santopadre and Verità 2000, 31; Towle *et al.* 2001, 7-10 and 38-44, table). This suggests the use of different mixed alkali sources.

Cobalt-containing glasses

Thirty-five plant ash glasses (n = 35) were translucent dark blue (Table 1); their dominant colourant is cobalt oxide (0.04 - 0.23 wt%). A combination of cupric oxide (averaging at 0.34 wt%) and cobalt oxide (averaging at 0.06 wt%) was responsible for the paler hue of fifteen translucent light blue samples (n = 15). Although cobalt minerals are scarce in nature, they are invariably associated with small amounts of other metals and trace elements, such as copper, nickel, iron, arsenic, sulphur, and silver (Henderson 1985, 279-280). For most of the Elateia glasses, the cobalt source can be characterized by high manganese, zinc, and arsenic with low nickel contents (Table 1). The rest contain similar levels of manganese, nickel, and zinc, but they are arsenic-free. Most of the Mycenaean cobalt-blue plant ash glass from Elateia and Thebes contain higher levels of alumina but lower magnesia than their Egyptian counterparts. Five of the Uluburun ingots form a small group, slightly different from the Theban glasses in magnesia contents but similar in alumina levels, of about 1.86 wt% (Fig. 2). In Elateia plant ash blue glasses the colourant minerals used are apparently distinct from the arsenic-ferrous Iranian sources and the alum-ferrous Egyptian ores (Kaczmaczyck 1986, 373-374).

Thirteen LMHK mixed-alkali glasses (n = 13) were coloured by cobalt oxide (0.06 - 0.18 wt%) (Table 1). A single pale blue example was coloured by 0.06 wt% cobalt oxide and 0.87 wt% cupric oxide. In these glasses the cobalt source employed differs from that used in the plant ash glasses due to the highest alumina contents (2.76 - 2.95 wt%). The elevated amount of iron (averaging at 1.19 wt%) points to an iron-rich cobalt mineral. These glasses are further characterized by elevated copper levels (averaging at 1.37 wt%), low levels of manganese, high levels of nickel, and an absence of arsenic.

LMHK Elateia and Frattesina cobalt-blue glasses can be distinguished by their cobalt and copper oxide contents. Moreover, most Elateia blue glasses contain higher iron and nickel

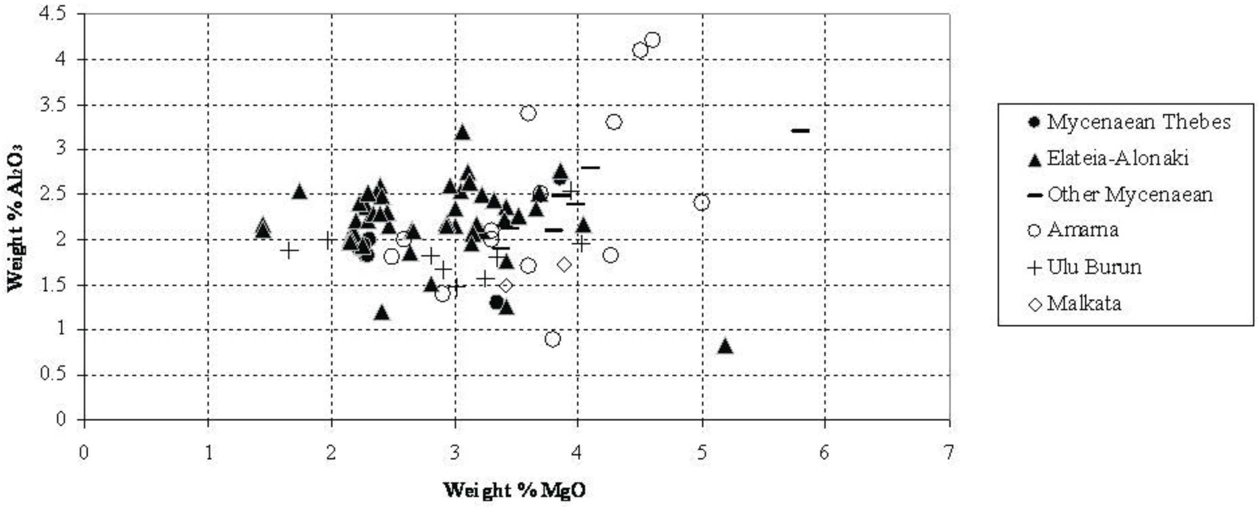

Fig. 2. A plot of Al_2O_3 versus MgO in cobalt blue glasses from Elateia-Alonaki, Mycenaean Thebes, Egypt, Mesopotamia and Uluburun.

contents. This seems to indicate the use of different cobalt bearing minerals as colourants (Fig. 3). One potential source, the ferro-nickel ores found at Laurion and Larymna in Greece (Tite *et al.* 2005), however, is unlikely to be the source due to the positive correlation of copper and iron in Elateia blue LMHK glasses (Nikita and Henderson 2006, 118-119).

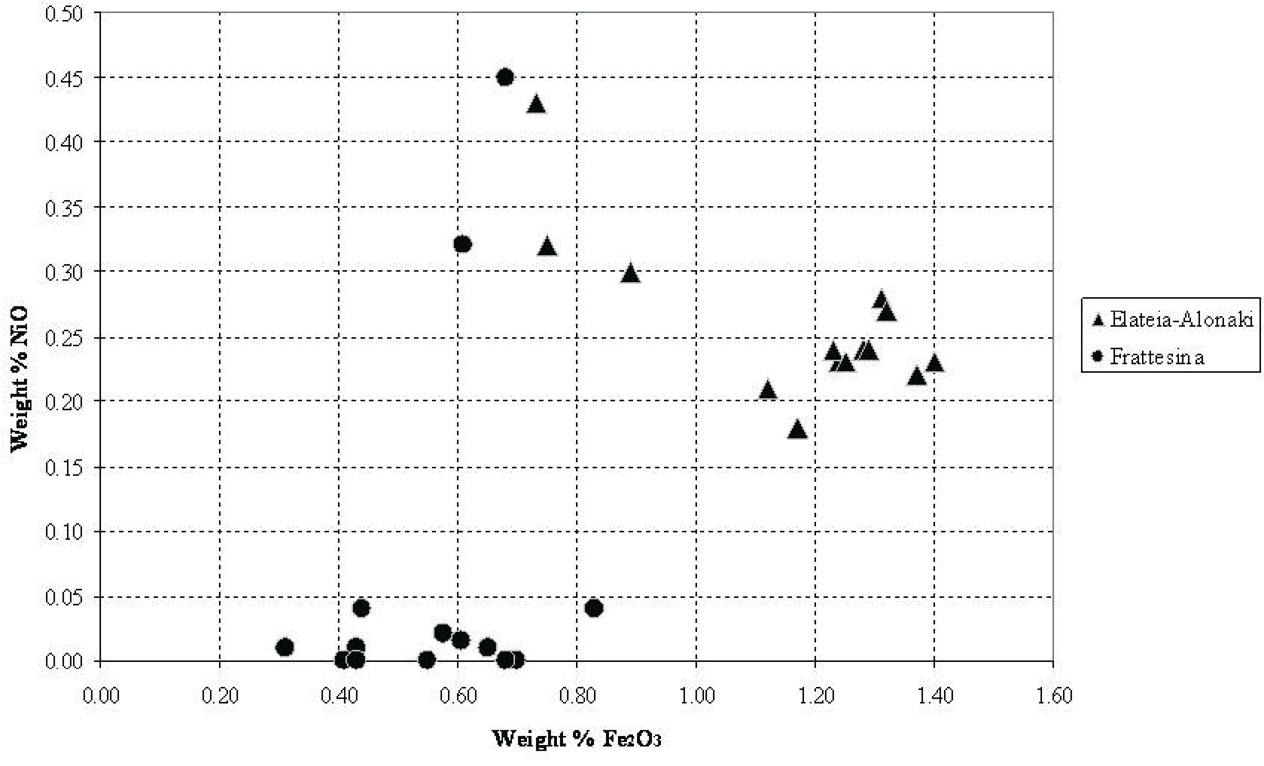

Fig. 3. A plot of NiO versus Fe_2O_3 in cobalt blue mixed alkali glasses from Elateia-Alonaki and Frattesina.

Interpretation of the results of the scientific analysis

There are compositional differences between the Mycenaean base plant ash glasses from Elateia and Thebes and the contemporary plant ash glasses from Mesopotamia and Egypt (Fig. 1). Therefore, there is the possibility that raw glass was not only imported but actually produced in Mycenaean Greece. In the light of recent analysis the tight compositional group points to a single supply centre, the palace of Thebes being a possible candidate. Either the settlement of Elateia obtained finished glass beads or raw glass was re-melted and shaped into beads there (Nikita and Henderson 2006, 119-120). However, on typological grounds the glass relief-beads from Elateia-Alonaki do not seem to differ from relief-beads in other parts of Mycenaean Greece. Further typological and scientific analysis will be needed to clarify the relationship of Mycenaean glass beads and to establish the production centres (Nightingale 2000; Nightingale 2008).

There was a demand for cobalt-blue glass in the Mycenaean Aegean even though cobalt-rich ores are scarce in the Aegean. Thus cobalt-blue glass ingots and/or cobalt-rich mineral ores were most probably imported by a Mycenaean glass-making centre for colouring locally made Mycenaean plant ash glass (Nikita 2003a; Nikita and Henderson 2006, 119). At the same time, non-cobalt glasses seem to have been imported either in raw form or as finished beads (Fig. 1), as is indicated by a group of glasses with elevated potassium and magnesium levels, which fall within the range of glasses from Mesopotamia.

The breakdown of the political and economic system of the Mycenaean palaces (end of LH IIIB, *c.* 1190/1180 BC) apparently ended the production of Mycenaean glass and faience beads (together with most other palatial crafts). In the post-palatial period the number of Mycenaean glass and faience beads used as grave goods falls fast; by the Protogeometric period they are mostly gone. On the other hand there are new elements like a renewed interest in inlaid as well as layered round, horned or triangular eye beads, in trail decorated beads, the appearance of singular, previously unknown types of beads and in the Protogeometric period the dominance of faience disc beads in larger parts of the Aegean. All these elements show connections both to the West and to the East. They are not uniformly distributed throughout the Aegean but there are differing combinations of types and different numbers of beads *(cf.* the cemeteries of Knossos, Perati and Lefkandi: Nightingale in print a; Nightingale in print b, with further references).

Two of these new elements are the annular beads and a horned stratified-eye bead of mixed-alkali LMHK glass in four tombs of Elateia-Alonaki dating to the end of LH IIIB and mostly to the post-palatial period of LH IIIC (12th century BC; Fig. 4). On the one hand this small group of mostly cobalt-blue beads perpetuates the old Mycenaean predilection for dark blue glass used in burial gifts (Nikita 2003a, 33-34); on the other hand they are part of a set of new features, which arrive at the end of the palatial and in the post-palatial period. The mixed-alkali glasses at Elateia-Alonaki and Thasos in the Northern Aegean could have been imported from the West (as finished beads or as raw glass, by transferring the technology), *e.g.*, from Frattesina in Northern Italy, despite differences in the glass composition (Henderson 1990; Henderson 1992, 804-806, table 1, p1. 368; Towle *et al.* 2001, 7-10, 38-44, table), since currently there is no *apparent* evidence for a Mycenaean or Near Eastern/Egyptian tradition of mixed-alkali LMHK glass production. Recent research emphasizes the strengthening of Italo-Mycenaean contacts in the 12th century BC (in LH IIIC; *cf.* several papers in Laffineur and Greco 2005). Already in the Mycenaean palatial period Mycenaean faience beads reached Italy and an exchange of ‘know-how’ between the Mycenaean and the Italian vitreous industries is possible (Rahmstorf 2005; Nightingale 2008; Nightingale in print b). Italian contacts in Elateia-Alonaki are attested by *e.g.*, the presence of Italian metal implements and amber beads of the Tiryns type (S. Deger-Jalkotzy and Ph. Dakoronia, pers. comm.), which are popular in the Aegean and especially in Italy.

Conclusions

For the first time we can show that the glass beads from Elateia-Alonaki have a chemical composition which is distinctive from glass vessels that have been found in Egyptian and Mesopotamian contexts. Glasses from the three areas have distinctive plant ash compositions, and this suggests that the primary manufacture of raw plant ash glass occurred in Late Bronze Age

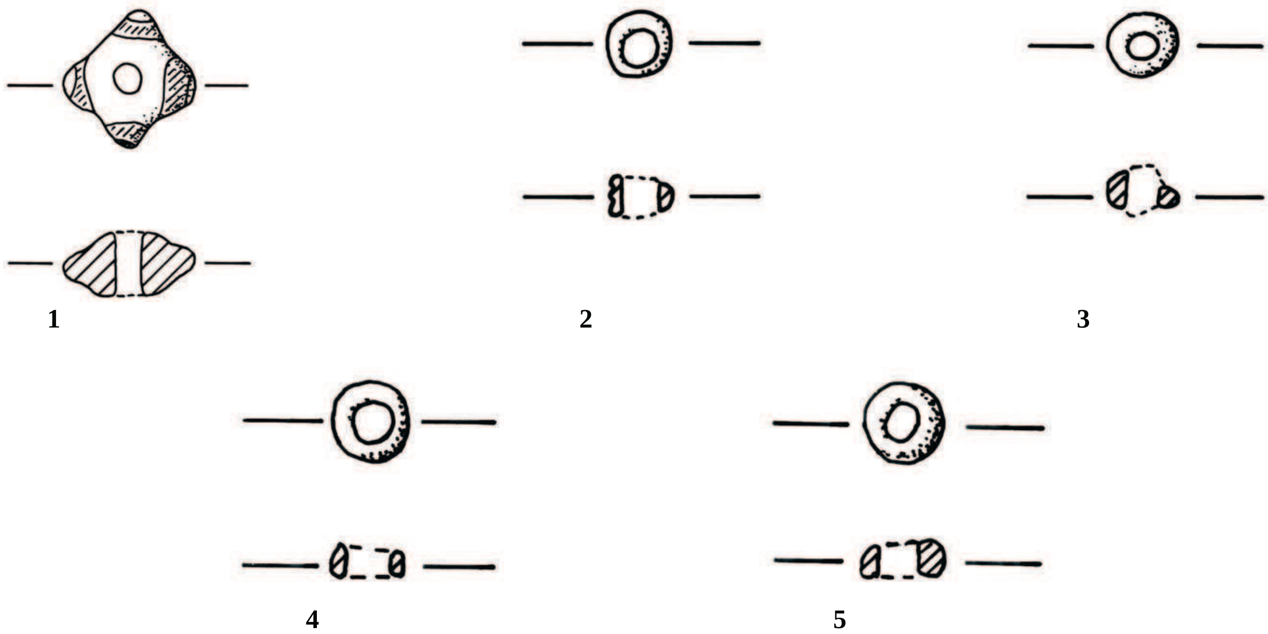

Fig. 4. A horned stratified-eye bead and examples of mixed-alkali (LMHK) annular glass beads from Elateia-Alonaki: 1) T. LVII/5δ; 2) T. LVII/5ογ/7; 3) T. LVII/5ιθ/9; 4) T. LVII/5ιγ/3; 5) T. XXIV/20bf/1 (all drawings by G. Nightingale).

Greece. The mixed-alkali (LMHK) glass from 12th/11th century BC contexts at Elateia-Alonaki represents a relatively new glass composition for the area which is mainly characteristic of Italy and the West, but not of the East. Both types of glass were coloured with a cobalt rich mineral.

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