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# Natron glass production and supply in the late antique and early medieval Near East: The effect of the Byzantine-Islamic transition

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ABSTRACT

Palestine and Egypt supplied the Mediterranean and Europe with virtually all of its glass for most of the first millennium CE. While the Muslim conquest in the 7th century saw major political and economic adjustment, immediate changes to material culture appear to have been minimal. This paper examines the impact of the Byzantine-Islamic transition on the natron glass industry of Palestine from the 7th to 12th century. A series of 133 well-contextualised glass vessels from selected excavations in modern day Israel have been analysed for major, minor and trace elements using LA-ICP-MS. These glasses are assigned to previously established primary production groups, allowing the elucidation of the chronology of key changes in glass production in the region. Results indicate a relatively abrupt compositional change in the late 7th - early 8th centuries, covering the reforming reigns of al-Malik and al-Walid, which marks the end of "Byzantine" glass production and the establishment of the furnaces at Bet Eli'ezer. At about this time there was an influx of glass of an Egyptian composition. Production of Bet Eli'ezer type glass appears to have been limited to a short time span, less than 50 years, after which natron glass production in Palestine ceased. Plant ash glass is first encountered in the late 8th-early 9th century, probably as a result of reduced local natron glass production creating the conditions in which plant ash glass technology was adopted. Egypt continued to produce natron glass for up to a century after its demise in Palestine. It is reasoned that the change and then collapse in natron glass production in Palestine may well have been as a consequence of a reduction in the quantities of available natron. This affected Palestine first, and Egypt up to 100 years later, which suggests that the factors causing the reduction in natron supply originated at the source and were long term and gradual, not short term events.



## 1. Introduction

The centuries following the Arab conquests in the Near East represent a period of great political, economic and social change, and how these changes are reflected in the archaeological record is an area of major interest. Glass is a category of material culture which exhibits significant change in composition around this time and which might be expected to yield important information on the broader developments that occurred.

It is widely recognised that glass production conformed to a centralised production model during the Roman and Byzantine periods (Nenna et al., 1997; Freestone et al., 2000; Degryse, 2014). Large tank furnaces in Egypt (e.g. Nenna, 2015) and Palestine (Gorin-Rosen, 2000; Tal et al., 2004), melted many tonnes of sand and natron into large slabs which were broken into chunks and distributed to a large dispersed network of secondary vessel fabrication workshops across the Empire and beyond.

While the general form of the glass industry in the first millennium CE is now understood, key issues remain to be resolved. These include, in particular, the nature and timing of technological change to plant ash glass, the changing distribution of primary production sites and the supply of glass between different regions of the eastern Mediterranean, and how these changes relate to wider social, economic and political developments of the time. An improved compositional and chronological resolution of glass compositional groups will ultimately facilitate a much increased

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understanding of the trade in glass across the ancient and early medieval worlds (Rehren and Freestone, 2015).

The present paper addresses key outstanding questions related to the chronology and characterisation of glass production groups evident during the Byzantine-Islamic transition (7–9th centuries). The aim is to develop a framework within which the major technological change from the use of mineral soda (natron) to soda-rich plant ash as a flux (Sayre and Smith, 1974; Gratuze and Barrandon, 1990; Shortland et al., 2006) may be better understood. Current understanding of the chronology of this change and its precursors is imprecise. In the core production area of Palestine, our information is based mainly on the analysis of material from primary production sites, which due to the absence of diagnostic material culture, can often be difficult to date. Furthermore, because the material analysed has been abandoned rather than utilised to make vessels, it is not clear that it is fully representative. These issues are addressed below by the analysis of glass vessels from well-defined archaeological contexts and, where possible, of diagnostic forms.

This paper presents major and trace element compositions of over one hundred well-dated glass vessels of natron-type glass from excavated consumer sites in Israel. The much improved chronological resolution, coupled with an analytical technique with high accuracy and sensitivity, has resulted in a significantly improved understanding of both the chronologies and compositions of the principal chemical groups. This has enabled us to track changes in group dominance and technology, improving our understanding of the relationship between Palestinian and Egyptian glass production, and providing greater understanding as to when and why plant ash glass appeared in the Levant. These changes are discussed within the wider economic, political and cultural developments of the period.

## 2. Materials and methods

### 2.1. Sites and samples

The results of the analysis of 133 natron glass vessels from ten sites in Israel are presented here. Plant ash glasses were also identified but will be the subject of detailed consideration in a separate paper which will identify the types and provenance, and discuss the potential origins of and the mechanisms in which plant ash glass technology came to be used in Palestine (Phelps Forthcoming).

The analysed vessels cover the Late Byzantine/Early Umayyad to Fatimid periods (7th to 12th century). They are from controlled excavations undertaken by the Israel Antiquities Authority (IAA) from 17 excavations at ten sites, selected to provide a wide geographical spread and range of settlement types. The samples were chosen from mainly diagnostic fragments of common, domestic vessel types – bottles, bowls, goblets, beakers – with unique and rare forms avoided where possible. Some decorated forms – e.g. trailed, mould blown, pinched and tonged types – and coloured types were included, such as cobalt blue and manganese decoloured types, but other intentionally coloured glass (e.g. copper and lead) were excluded. Dating was paramount in sample selection, and relied upon a combination of context (stratigraphy, pottery and coinage), vessel form and fabric (colour, fabric quality). Typological dating using glass is relatively advanced in Israel (Gorin-Rosen, 2010a). A sample catalogue with context details, colour, dating, form and decoration can be found in Appendix C (supplementary material).

The vessels derive from three types of site, they can be categorised as: urban centres, military sites and rural settlements (Fig. 1). The urban centres include excavated locations in Bet Shean, Caesarea, Jerusalem, Ramla, Sepphoris and Tiberias. Ramla was unique in Palestine, being the only settlement to have been newly founded post-conquest (c. 715) as a Muslim city. It was to become very prosperous due to its administrative role and important trading position. The others cities were ancient and, on the whole, continued to have economic prosperity post-conquest (see Avni, 2014; Petersen, 2005), although Bet Shean and Caesarea declined in size due to their loss of administrative roles to Tiberias and Ramla, which took over as regional capitals of Jund al-Urdunn and Filastin respectively. Caesarea also lost links to Mediterranean trade networks. Ashdod Yam and Ha-Bonim were military installations dating from the late 7th century forming part of a Ribat system of 20 forts along the Palestine coast (Vunsh et al., 2013; Khalilieh, 1999). The rural sites comprise Ahihud, a small settlement east of Akko (Acre) in the north, and Nahal Shoval and Tel Rosh in the south of the country. The latter two were small settlements within a prosperous agricultural region in the northern Negev Desert near Beersheba. Site details are shown in Table 1. Note that a site License (or Permit) for each excavation is listed, this is the number provided to excavations by the IAA and is useful for linking this work to the published reports, particularly as some locations have more than one excavation.

### 2.2. Analytical methods

Analysis was by LA-ICP-MS (laser ablation inductively coupled plasma mass spectrometry) on small detached glass fragments at the Ernest-Babelon laboratory, IRAMAT, Orleans, France. Elements were quantified using a Thermo Fisher Scientific Element XR mass spectrometer equipped with a three stage detector utilising a dual mode (counting and analog) secondary electron multiplier (SEM) giving a linear dynamic range over nine orders of magnitude associated with a single Faraday collector. This increases the linear dynamic range by three orders of magnitude, which is particularly important as the dilution of samples is impossible with laser ablation in contrast to solution ICP-MS, and therefore allows the analysis of major, minor, and trace elements in a single run regardless of their concentrations and their isotopic abundance. Analysis was performed over two campaigns. Campaign 1 (samples from Ahihud, Sepphoris and Bet Shean) used a VG UV-laser, generated by a Nd YAG pulsed beam and operating at 266 nm wavelength, 3–4 mJ power and 7 Hz frequency. An argon stream (1.15–1.35 l/min) carried the ablated material to the plasma torch. Campaign 2 (the remaining sites) used a Resonetics RESOlution M50e ablation device. This is an excimer laser produced by argon fluoride at 193 nm wavelength, and operated at 4 mJ and 7 Hz. It is a dual gas system with helium (0.6 l/min) released at the base of the chamber, which carried material to an argon stream (1.2 l/min). For both campaigns ablation time was set to 70 s: 20s pre-ablation to reduce potential contamination and 50s collection time. Fresh fractures were analysed where possible to further avoid contamination or corrosion. Blanks were run between samples. Spot sizes were set to 100 μm (although reduced to 70 μm when saturation occurred). For campaign 1, two areas were analysed per specimen to investigate possible heterogeneity in the samples. The agreement between the sites were found to be consistently good, so for Campaign 2 only one spot was analysed per sample. During analysis live counts were observed so that element spikes signifying the presence of inclusions or other compositional heterogeneities could be identified. When this occurred the results were discarded and a new site selected.

Calibration was performed using five reference standards – NIST610, Corning B, C and D, and APL1 (an in-house standard glass with composition determined by Fast Neutron Activation Analysis which is used for chlorine quantification) – which were run periodically to correct for drift. The standards were used to calculate the