LATE ANTIQUE AND BYZANTINE MOSAIC TESSERAE & GLASS PRODUCTION

The project set out to shed light on the manufacture of Byzantine glass mosaic tesserae about which little is known despite the widespread use of glass mosaics in Byzantine monumental decoration. The main aim was to determine the compositional characteristics of mosaic assemblages from different archaeological contexts in order to elucidate the chemical variability among sets of samples and to identify geographical and/or chronological patterns in the chemical make-up of tesserae. Since the elemental composition of the tesserae may reveal the specific source of the raw glass and/or the raw materials by way of comparison with known primary glass production groups, the provenance of ancient glasses can be indirectly ascertained. With this it was hoped to gain substantial insights into artistic practices during the Byzantine period and into the cultural and economic exchange within the Byzantine Empire and beyond. To explore how mosaic making related to contemporaneous Byzantine glass-making traditions, other glass artefacts (i.e. vessels and windows) from Byzantine contexts were also included in this project.

The archaeological evidence for the primary production of glass during the Byzantine period other than the glass making installations along the Levantine coast is relatively scant. This is particularly intriguing in view of the extensive glass finds from throughout the Byzantine domain and the fact that the primary glass production in Palestine cannot account for some of the glass found, for instance, in Byzantine Butrint, Pergamon and Sardis (Brill, 1999; Schibille 2011a & 2011b). Based on the seminal paper by Sayre and Smith from 1961, ancient soda-lime-silica glass is typically divided into two distinct types: on the one hand, glasses with low potassium and low magnesium contents that were produced using a relatively pure mineral soda from Egypt; on the other hand, glasses with elevated levels of magnesium and potassium that are associated with the use of plant ash. In the period of interest (4^{th} to 12^{th} century), mineral soda glass prevailed until about the eight/ninth century, when mineral soda was increasingly substituted with plant ash fluxing agents. These are the two glass types commonly found in the eastern Mediterranean as well as Mesopotamia. New analytical evidence obtained within the scope of the Marie Curie IEF project puts into doubt the limitation in the production and consumption of glass at least as regards the middle Byzantine period (eight to thirteenth centuries) and suggest that additional, as yet unknown compositional types of raw glass were in circulation and possibly even manufactured in what is now Turkey. The study of the glass finds from sixth- to fourteenth-century Pergamon (Schibille 2011a) established the existence of a glass group among the eight- to thirteenth-century samples with high levels of alumina ($\geq 5\%$, see Fig. 1a) that is highly unusual for European and Middle Eastern glass of this period. Judging from the trace element patterns and elevated boron and lithium concentrations (Fig. 1b), these glasses were produced with a mineral soda different to the Egyptian natron from the Wadi Natrun, suggesting a possible regional Byzantine primary glass production in Asia Minor. The Pergamon assemblage thus demonstrates that there is yet a lot to be explored as regards the developments in the manufacture of Byzantine and early Islamic glass.

Similarly, the elemental analyses of the sizeable glass assemblage from late Roman and early medieval Butrint (Albania) identified compositional glass groups that do not correspond to either of the known primary glass production types from Egypt or the Levantine coast, but that display parallels with early medieval glass from central and northern Europe (Schibille 2011b). The compositional variations among the glassware from Butrint revealed a great complexity and a shift in the supply of glass to a single consumer site that was strategically located on the maritime trade routes between the eastern and western Mediterranean. Most notably, there is a distinct prevalence of Egyptian glass types among the early medieval glass finds from Butrint. Ample evidence points furthermore at the recycling and re-use of Roman material during the later occupation of Butrint (Schibille *in press*).

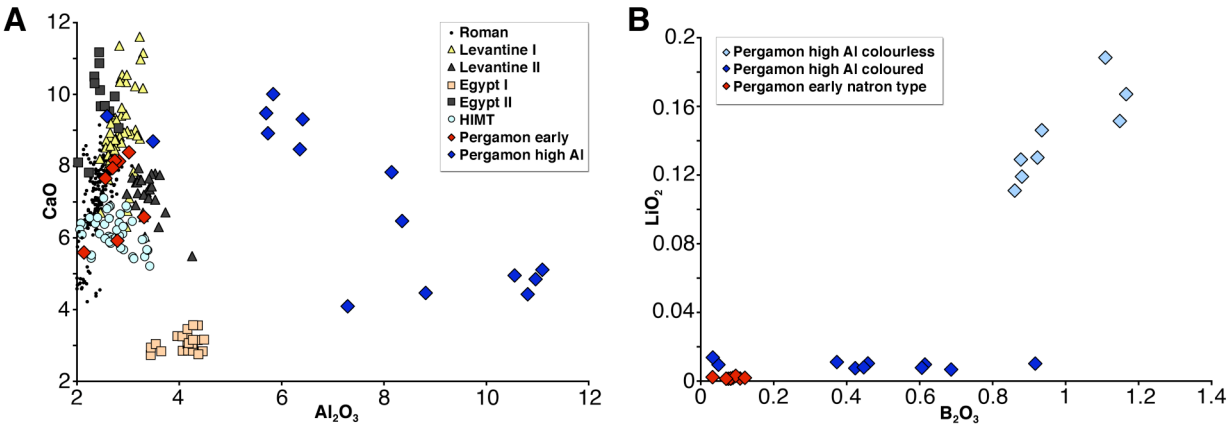

Fig. 1: Results from the Pergamon assemblage (Schibille 2011a) (a) Lime and alumina concentrations of the Pergamon assemblage in relation to established primary glass groups: Roman glass from Italy (Arletti *et al.* 2005; Mirti *et al.* 1993; Silvestri 2008; Silvestri *et al.* 2005&2008); Levantine I glass from Apollonia, Dor and Jalame; Levantine II glass from Bet Eli'ezer; HIMT glass from Augusta, Billingsgate and northern Sinai (courtesy of I. Freestone) Egypt I and II glass (B. Gratuze, unpubl. dissertation, University of Orleans 1988). (b) Exceptionally high boron and lithium concentrations are present in the high alumina glasses from Pergamon.

A third project brought to completion within the 2-year fellowship was concerned with the detailed chemical (EPMA, LA-ICP-MS) and microstructural (XRD, SEM-BSE) analysis of glass tesserae from Sagalassos (Turkey). This identified important differences between Roman and Byzantine mosaic production (Schibille *et al.* under review b). While the characteristics of the Roman tesserae suggest a centralised organisation of the manufacture of mosaic tesserae, both at the primary and the secondary production stages, the Byzantine samples reflected a diversification in the making and supply of mosaic tesserae during the Byzantine period. What is more, the chemical and structural evidence bear witness to different production processes of tesserae that are related to the colours of the samples, thus strongly implying a certain colour specialisation during secondary workshop practices (Fig. 2). The chemical data of other assemblages analysed that are yet to be fully evaluated seem to largely support these results and confirm the model of colour specialisation observed at Sagalassos (e.g. Knossos, Ephesos).

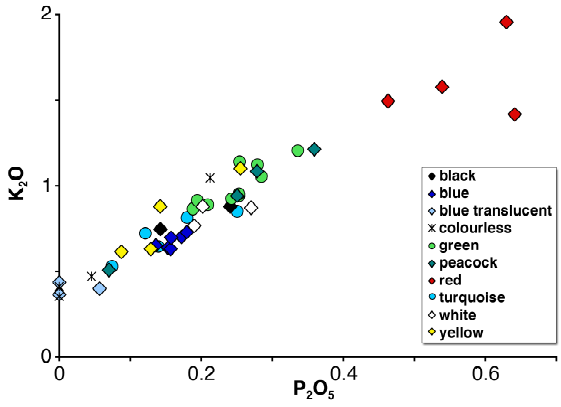

Fig. 2: Phosphorous and potassium are positively correlated in the mosaic tesserae from Sagalassos, demonstrating colour-dependent contamination levels and thus indicating a certain colour specialisation during secondary working (Schibille *et al.* under review b).

The investigation of opacifying and decolouring agents in both opacified as well as colourless glass (here defined as glass containing decolouring agents at levels indicating their intentional use) confirm a differential use of additives according to chronology (Schibille *et al.* under review a & b). Among the analysed glass finds, antimony, for instance, was exclusively found in opaque mosaic tesserae attributed to the third and fourth centuries CE and in colourless glass up to the early fourth century CE. These are only preliminary conclusions as our knowledge of the opacification and colouration processes in Roman and medieval glass making remains limited. Yet, the results obtained during the Marie Curie IEF have far reaching consequences for our interpretation of ancient glass assemblages and illustrate the need for more large scale and systematic comparative studies in order to map chronological and regional trends in the use of base glasses as well as colourants and opacifiers in more detail, based on which we might then be able to address some of the fundamental historical and cultural questions (e.g. economy, trade, political implications, artistic production, comparison with literary sources etc.).