

WHAT IS RECYCLING?

Recycling is seen as an obstacle but the fact that glass was reused, repaired and remelted in the past is an **opportunity**. Understanding recycling is a way for archaeological scientists and archaeologists to understand the complex paths taken by materials across time. Many behaviours are recycling; each with specific physical and chemical markers. Using terms of reuse, repair and remelting, broad chemical changes can be visible across large sets of data.

Recycling affects a materials' place in a physical and social world. It can be driven by cost, availability, or more complex ideas.

LARGE DATA SETS

Studies of Roman glass have shown that there were few primary production centres that exported widely. Several compositional groups are known but these have stronger correlations to chronology than geography. However, how these groups move and interact is more complex than usually discussed.

Large databases have been used to identify and quantify metal flow and recycling in the European Bronze Age[1]. Here a similar approach has been applied to Roman and Late Antique glasses, focusing on largescale trends. Over **50 previously published papers (over 3,000 glasses)** have been included in a database, and the results here are drawn from a subsection of these.

DATES USED

Few glasses are securely dated so the categories used are broad. Roman refers to any date from the first century BC to 450 AD, that could not be more securely dated. The labels used are as broad temporal indicators, not cultural.

Middle Roman Period : 150 - 350 AD

Late Roman Period : 350 - 450 AD

Early Byzantine Period : 450 - 650 AD

Middle Byzantine Period : 650 - 850 AD.

REUSE AND REPAIR

Reuse of glass is a direct form of recycling, with **no major physical changes**. The glass has undergone a change of purpose/function, place, owner or cultural significance. This can apply to the object as a whole or parts. There are many examples of this, almost all are archaeologically obvious, such as sherds pieced as amulets. This sort of recycling has long been discussed under a variety of different terms[2,6,7].

Reuse can be seen with both traditional archaeology, (note especially high-status, undeposited pieces, such as the Portland Vase) but also archeomterically.

It is seen in glasses that have forms and compositions consistent with earlier productions.

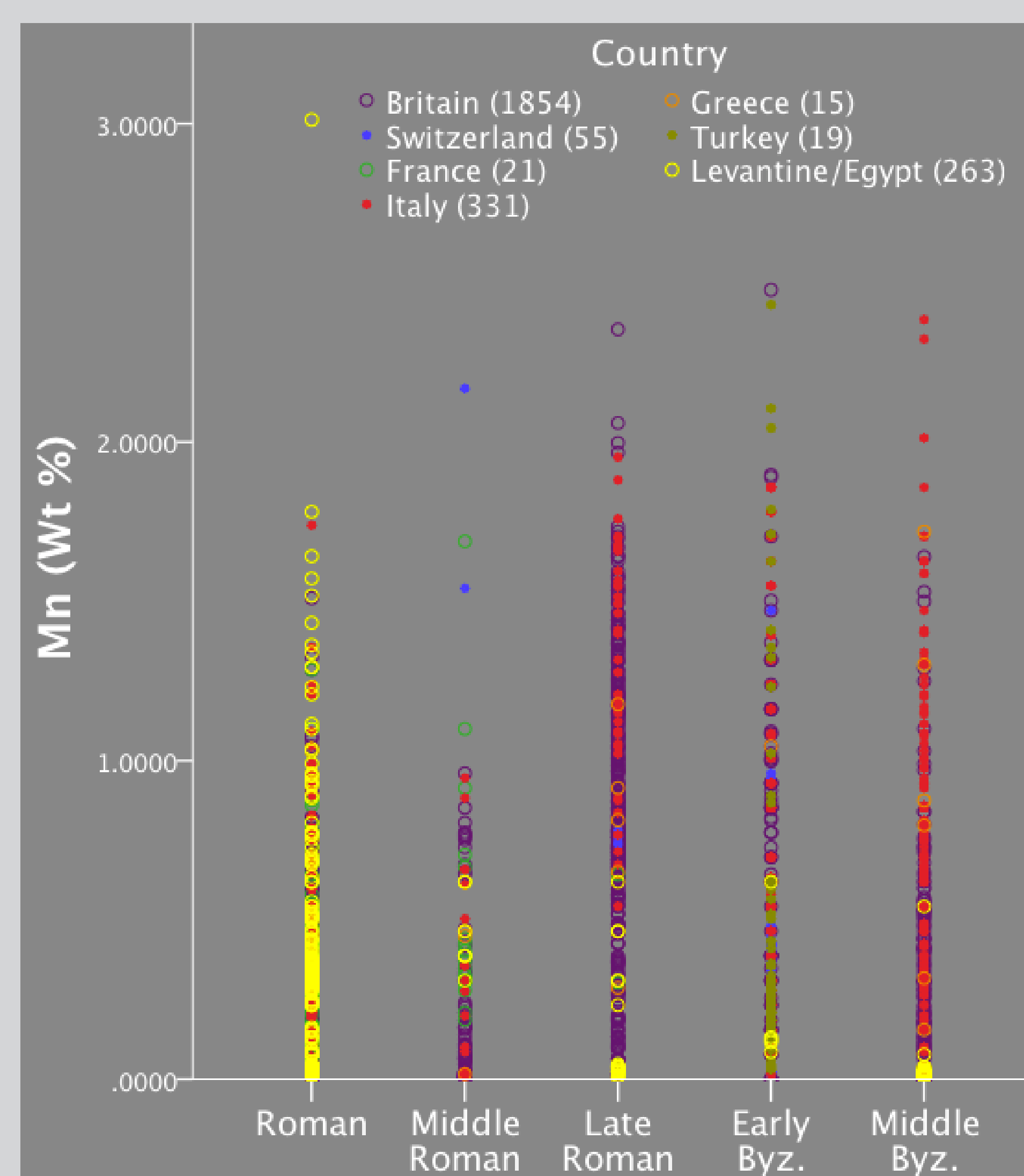
REMELTING

Encompassing what most consider 'recycling', the object(s) return to a liquid phase. Sherds can be collected together or individually melted to make beads or tokens. **Cullet production is strongly attested**, sometimes to achieve a finish, ie. coloured tesserae. Cullet recycling has many associated chemical changes, but is often dismissed as a complication. These changes illuminate industry processes.

Manganese has proven a useful identifier[3]. Around the end of the third century, glass (HIMT) is introduced with naturally high manganese, 1-2%[5]. This should be dominant by Early Byzantine.

Glasses from the fourth century should be Levantine or HIMT.

FIGURE 1



Wt% of Mn in Mediterranean and Northern European glasses.

HIGH MANGANESE GLASS?

As can clearly be seen in Fig. 1 and 2, Near Eastern glasses show little variation and Turkish/Greek glasses match the HIMT increases. Between these, **Northern European* glass stagnates** in the Late Roman Period and the Early Byzantine. All glasses are soda, so likely produced in the Near East/Egypt. European glass clearly elevates in Mn but not as high as HIMT.

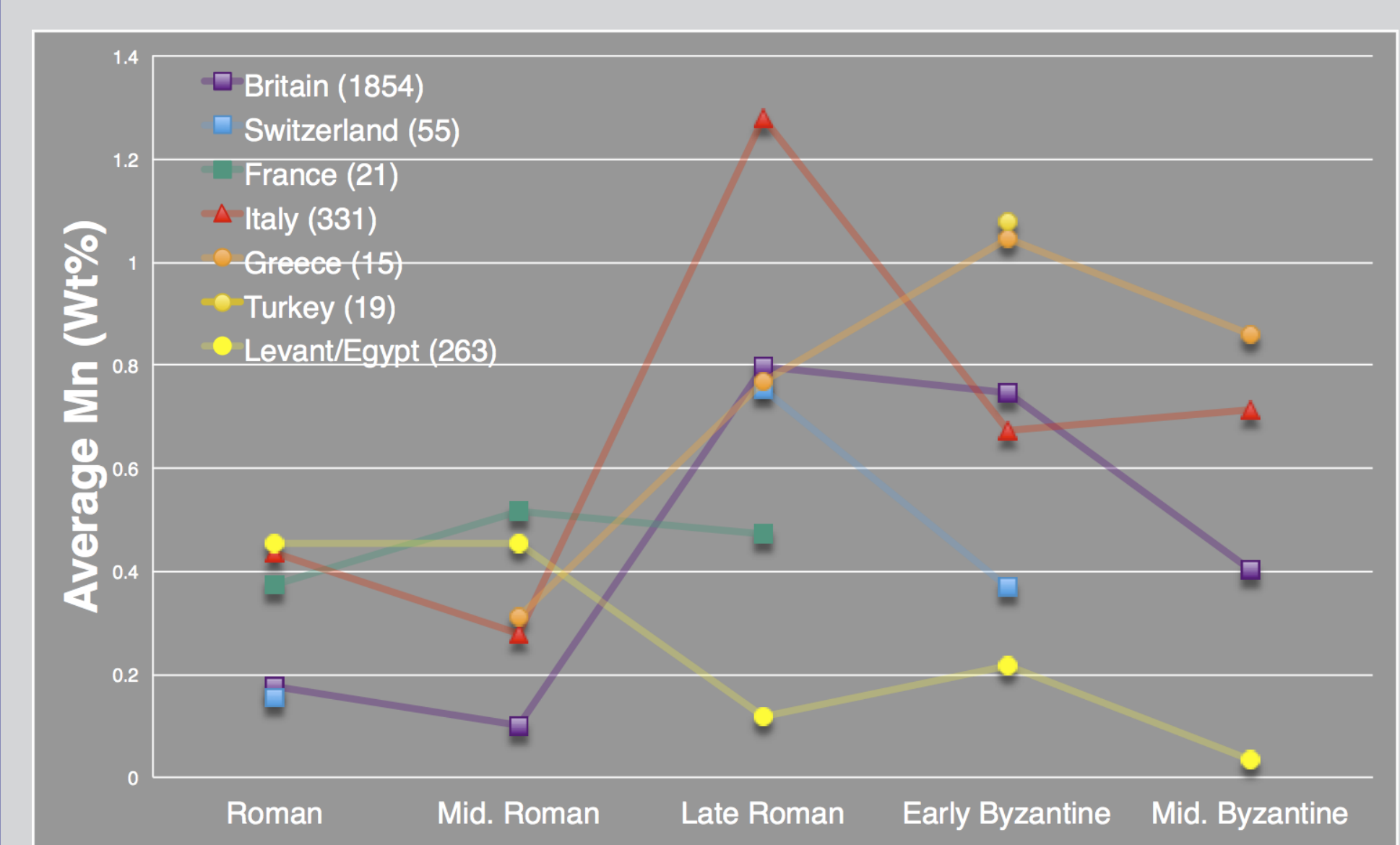
*The exception is 33 Italian glasses from the late Roman Period, all from Northern Italy.

NEW SOURCE OR RECYCLING?

There are two explanations: a **different source of glass** in Northern Europe, unlikely prior to Forest Glass.

The second is that the influx of fresh glass has slowed and the European industries are increasingly relying on cyclic recycling.

FIGURE 2



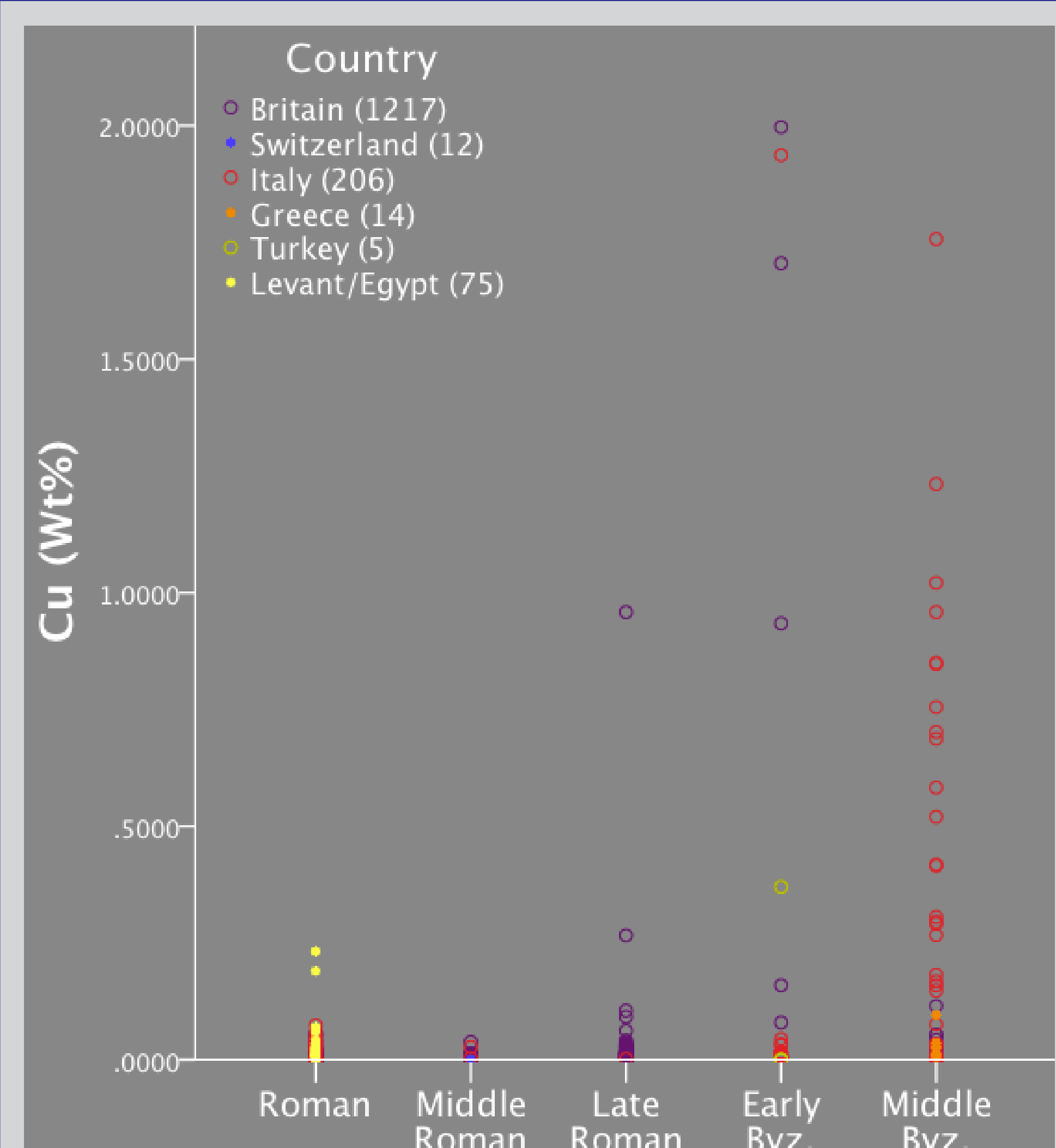
Average Wt% of Mn in Mediterranean and Northern European glasses.

COPPER

Copper doesn't occur in significant quantities in glass sands ($\approx 100\text{ppm}$)[4]. Its appearance in naturally coloured/colourless glass needs explanation. It is likely caused by the addition of deliberately copper-coloured cullet to mainly decoloured/uncoloured mix. Few Levantine/Turkish glasses have been published but all with low Cu values.

Once again European glasses diverge, pointing to recycling (Fig. 3).

FIGURE 3



Wt% of copper in colourless or naturally coloured glass.

CONCLUSIONS

This highlights the **divergence in glass production** as post-Roman structures emerge. In real terms, it shows a **stagnation in European glass, indicating a heavy reliance on recycling**. In time it will be clearer whether this occurs in intermediary countries, such as Italy or Greece, or is a self-perpetuating system.

The increasing use of large databases across a wide scale will show the place of recycling within ancient industry and improve understanding of glass trade.