

What have the Romans ever
done for us?
2000 years of glass recycling

Nadine Schibille (DR CNRS)

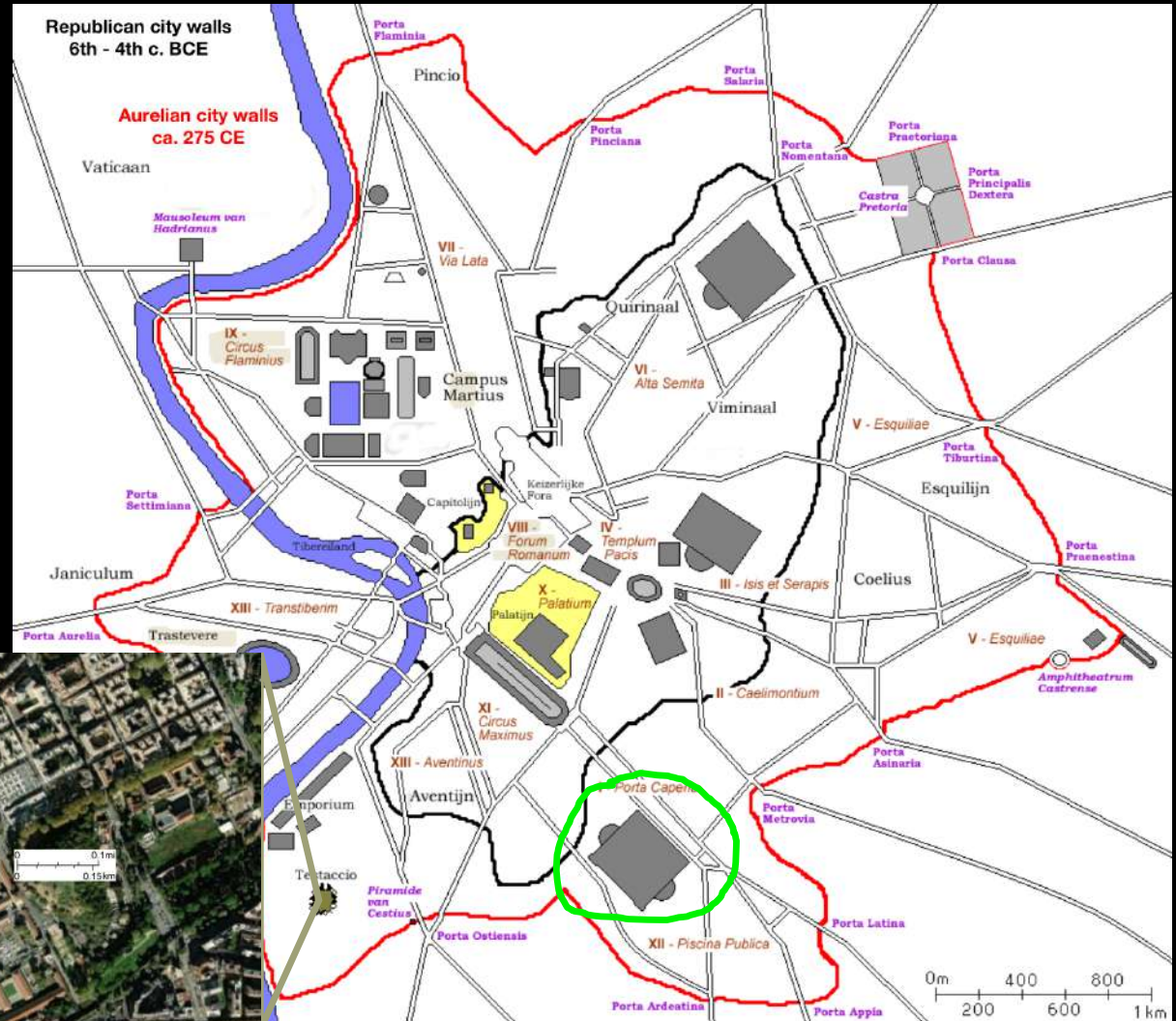
Jan Goeree, View of Mons Testaceus (1704), pen and black ink © Metropolitan Museum of Art, NYC



Waste management – Monte Testaccio



Havlicek & Morcinek (2016)



The curious thing – where is the glass?



The Baths of Caracalla in Rome, dedicated in 216 CE, reconstruction below © www.relivehistoryin3d.com



The curious thing – where is the glass?



Window glass

3,400 m² of window glass ⇒ 50 tons of glass

Glass mosaics

16,900 m² of mosaic decoration ⇒ 254 million tesserae ⇒ 380 tons of glass

Hardly any glass has been found !



Outline of talk



Glass production model in the 1st millennium CE

primary & secondary production

changes over time

Analytical evidence for glass recycling

Examples of recycling

Recycling markers

Archaeological & textual evidence for glass recycling

organisation of recycling

socio-economic dimensions



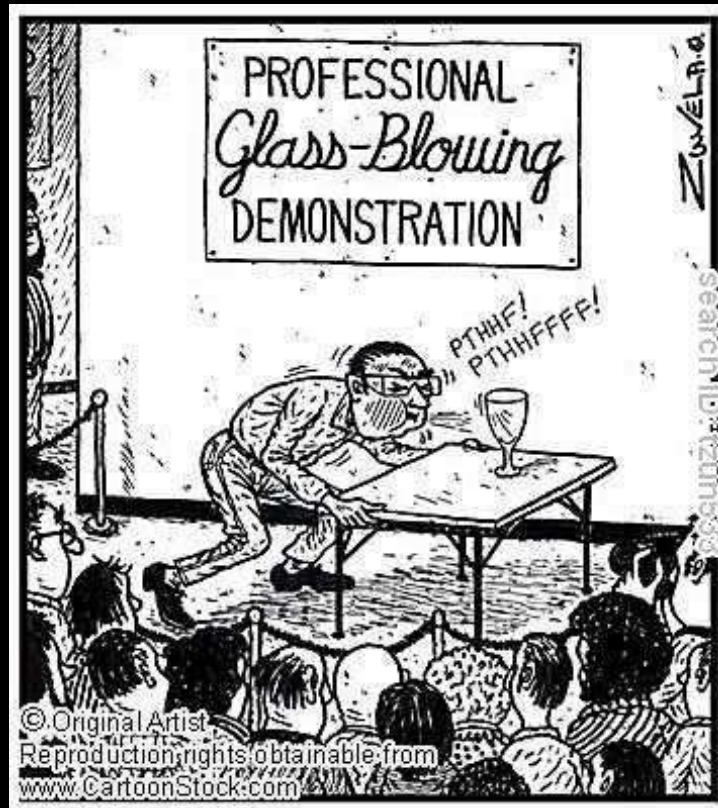
Broken glass from the Serçe Limani
shipwreck, ca 1025 CE
© INA GW-1393, REF 4378

Beginnings – early vitreous materials



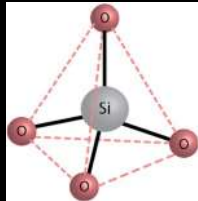
- Glazed stone (quartz and steatite) sometime during 5th millennium BCE in Egypt & the Near East
- Faience towards the end of 5th millennium CE, first in the Near East then in Egypt
- Glass beads and other small objects from the middle of the 3rd millennium CE
- First vessels and the beginnings of large scale glass making around 1500 BCE, first in Mesopotamia and shortly thereafter in Egypt

The invention of glass blowing



The Ein Gedi bottle. Mid-first century BCE.
H. 12.7 cm. The Israel Museum, Jerusalem.
© The Israel Museum, Jerusalem/by Peter Lany.

The stuff that ancient glass is made of



Network former

sand

quartz pebbles



Network modifier

Salicornia / Glasswort

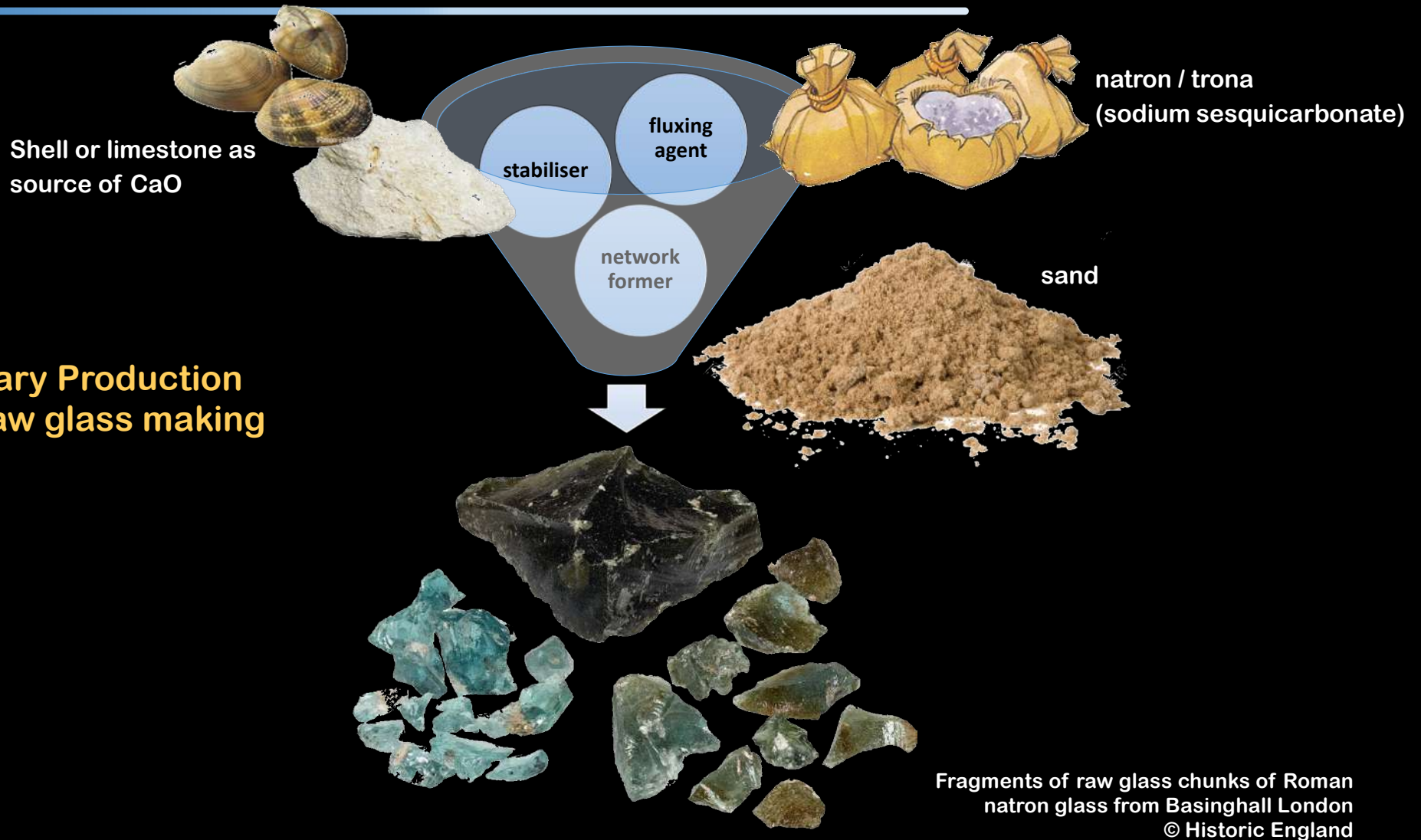


mineral natron



**Roman & late antique
< 800 CE**

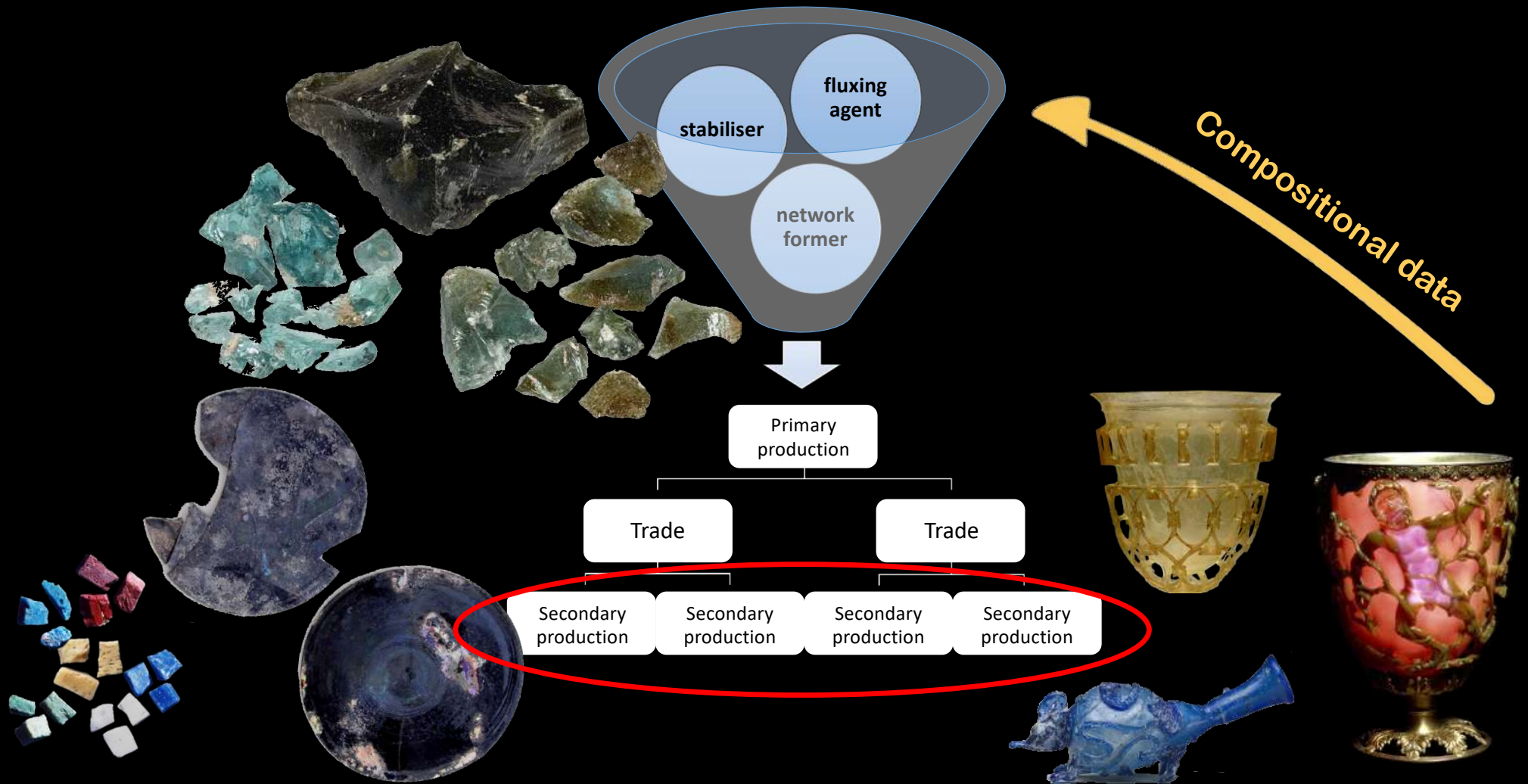
Primary versus secondary production – 1st millennium CE



Primary Production
i.e. raw glass making

Fragments of raw glass chunks of Roman
natron glass from Basinghall London
© Historic England

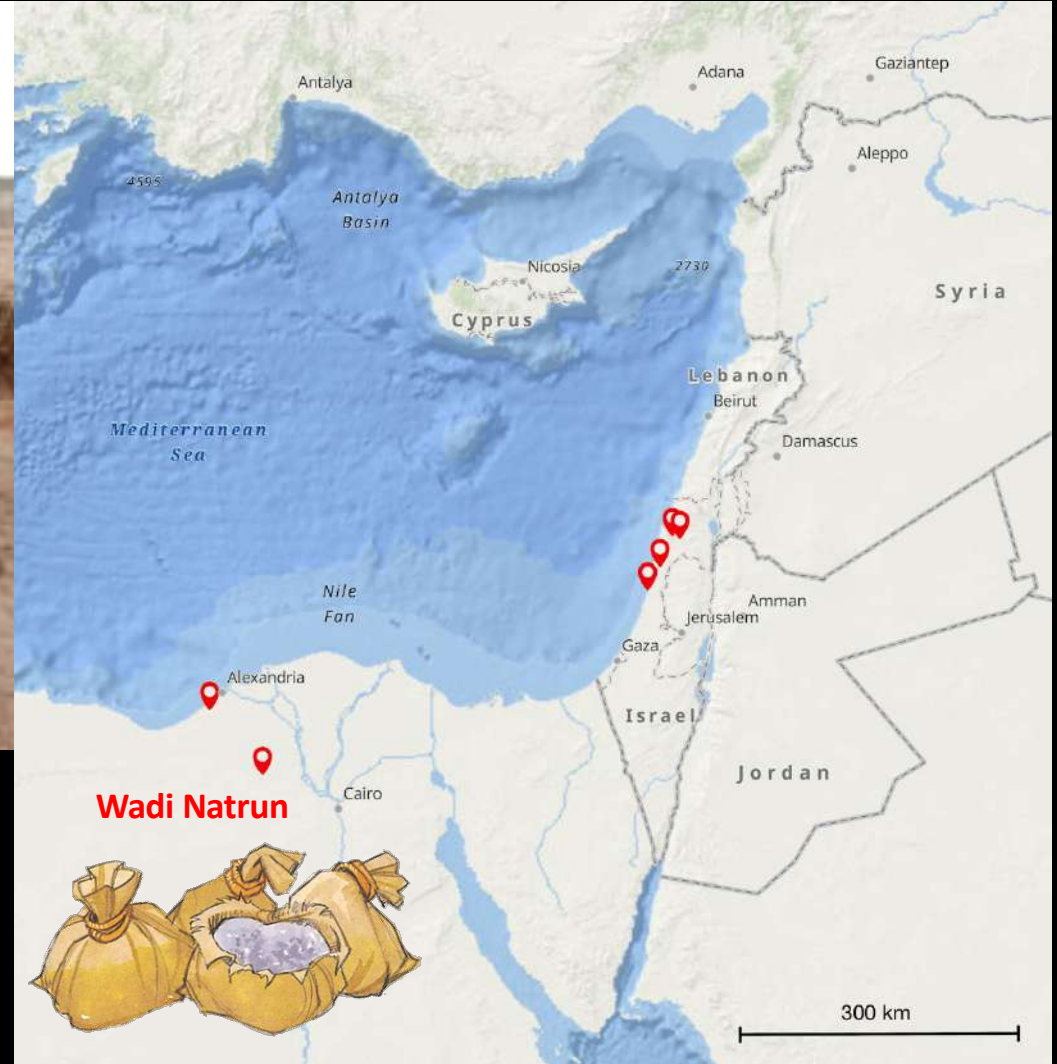
Primary versus secondary production



Primary production sites



Wadi Natrun, Beni Salama (Egypt), primary glass furnace
1st-2nd centuries A.D. © M.-D. Nenna



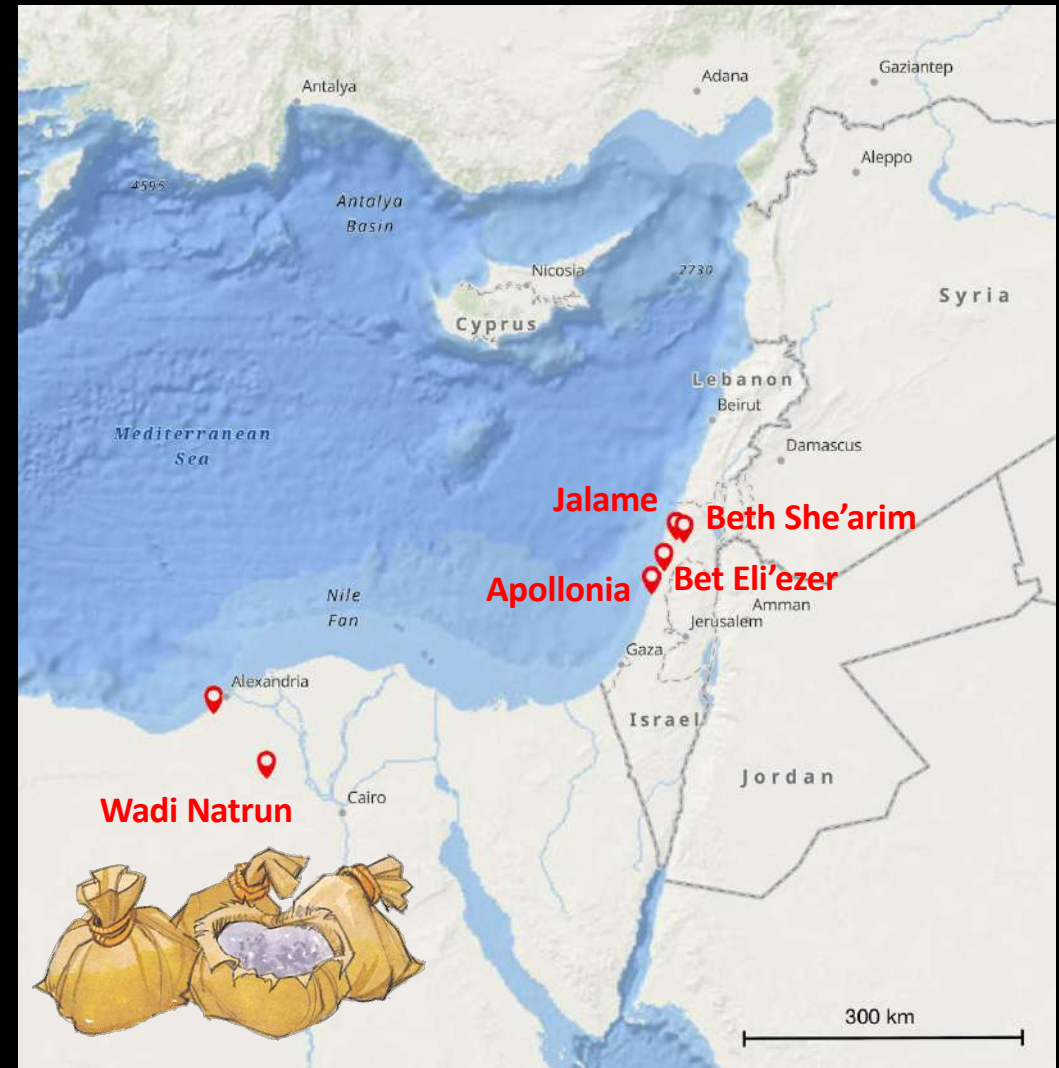
Primary production sites



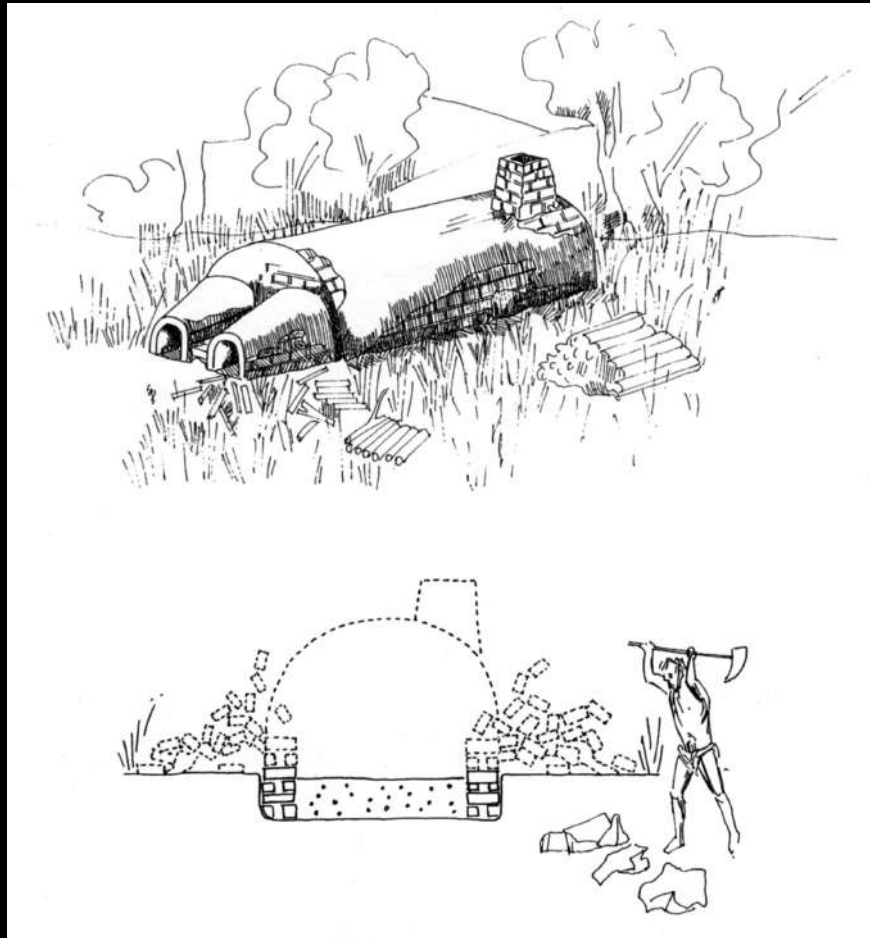
Bet Eli'ezer, Israel (7th-8th century), photo: J Rosen



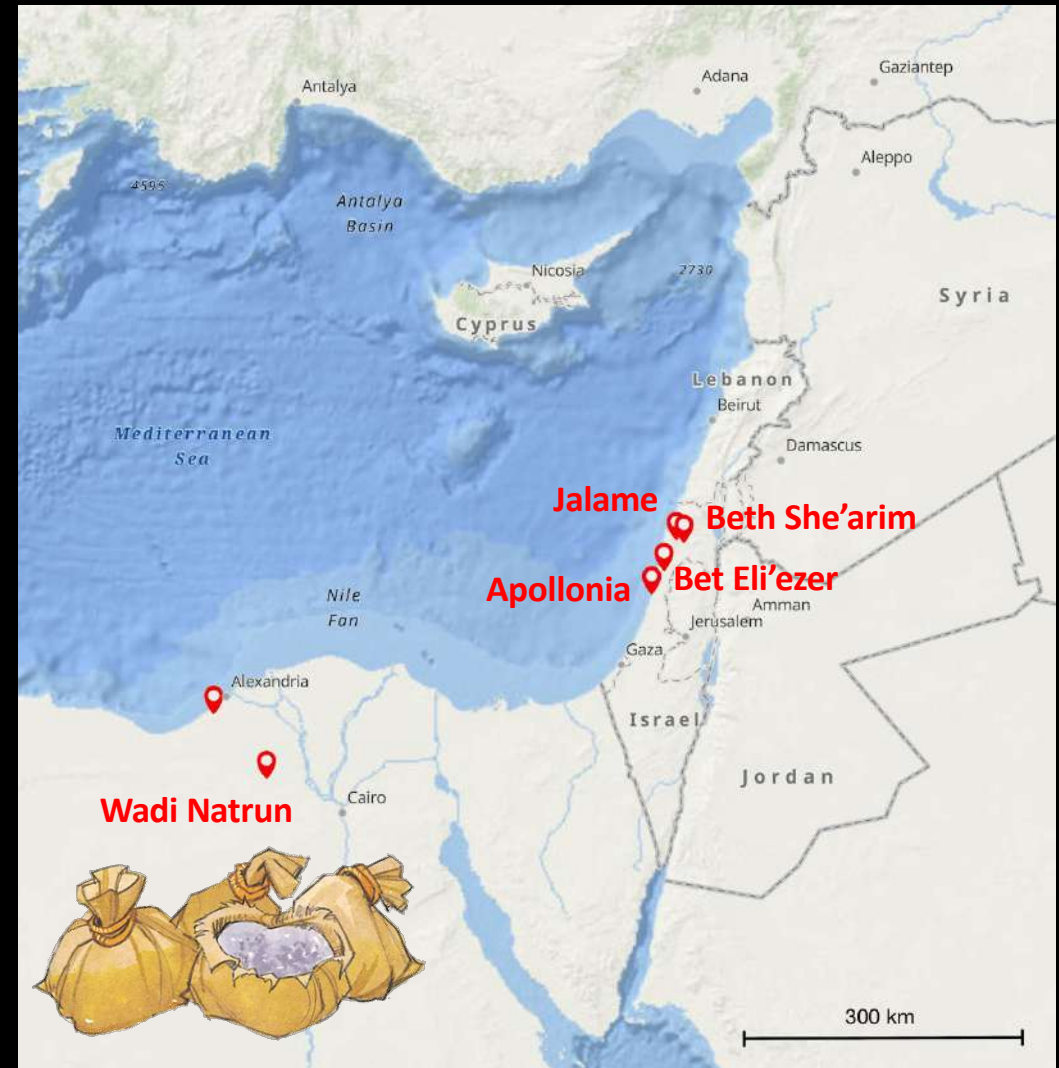
9 tons glass slab at Beth She'arim, Israel (9th century)
<http://www.cmog.org/article/mystery-slab-beth-shearim>



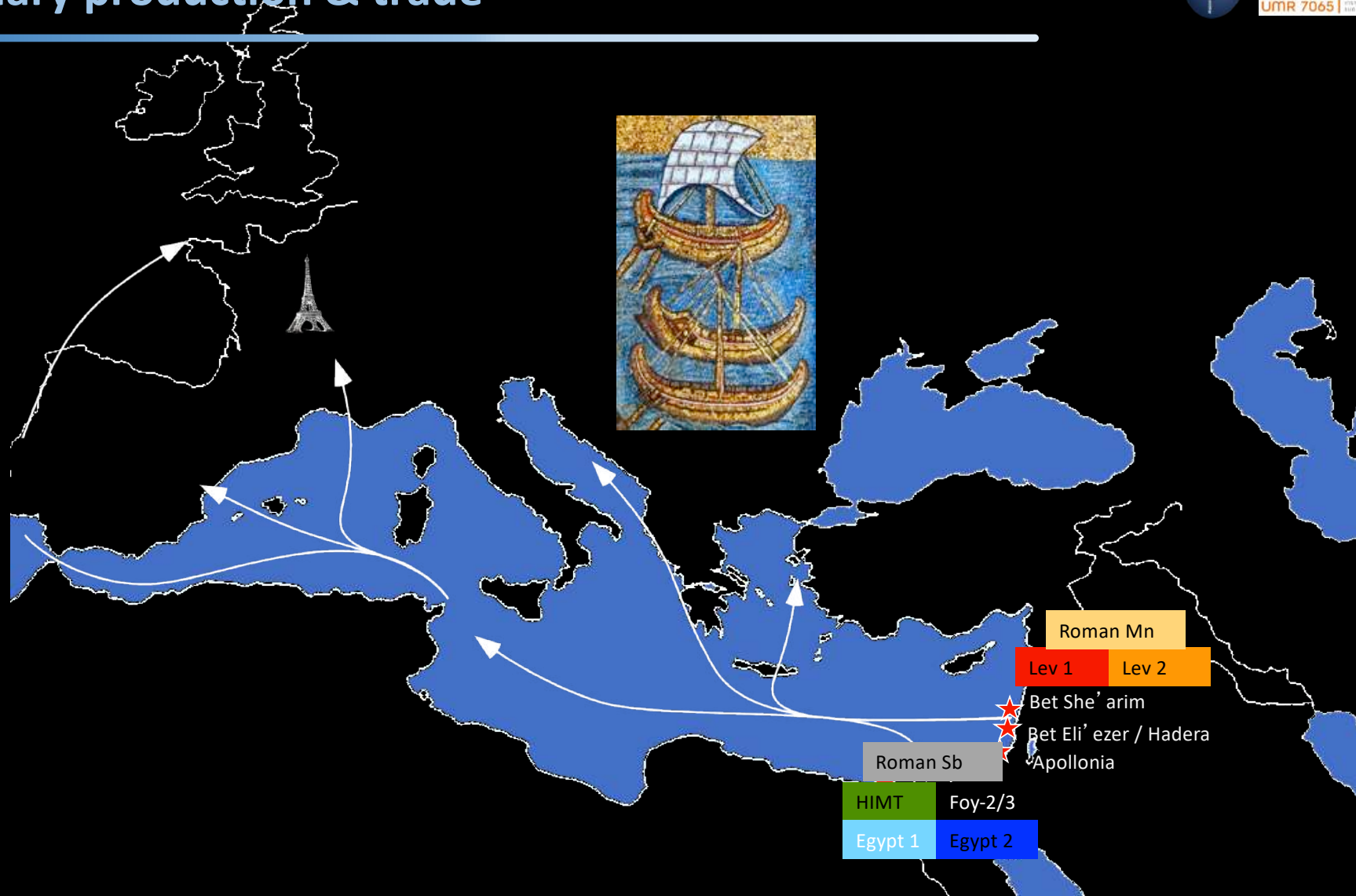
Primary production sites



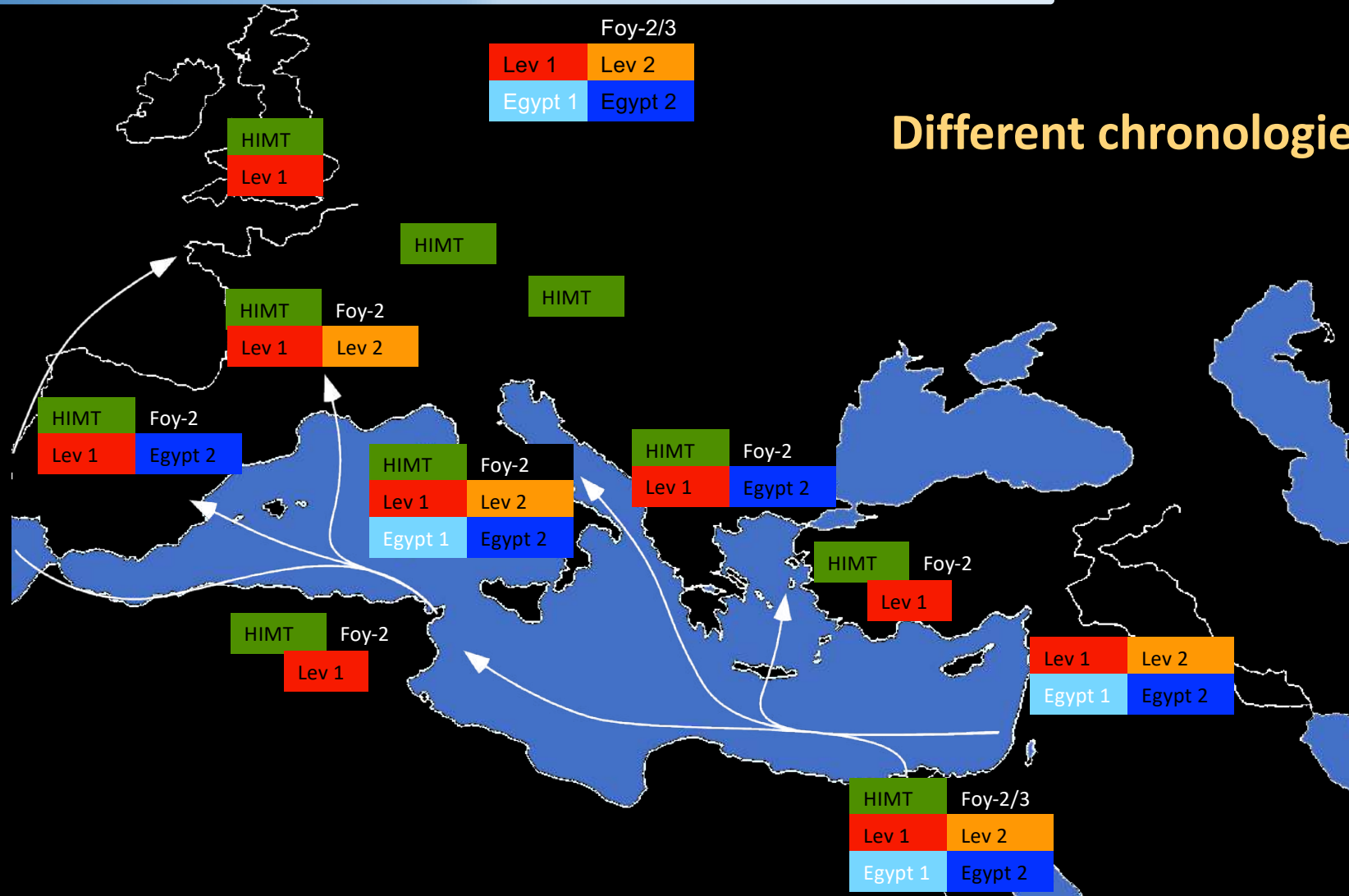
Reconstitution of the furnace at Bet Eli'ezer, Israel
Y. Gorin-Rosen (2000)



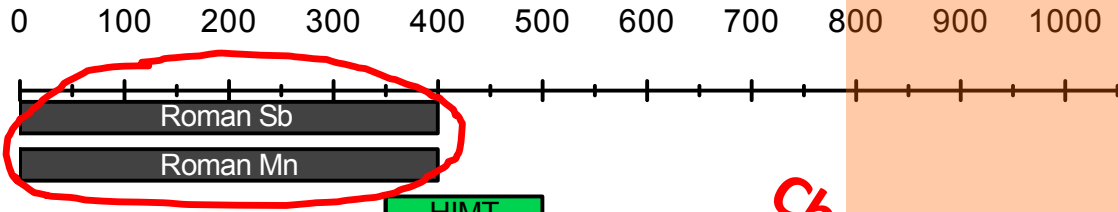
Primary production & trade



Distribution patterns of late antique natron glass

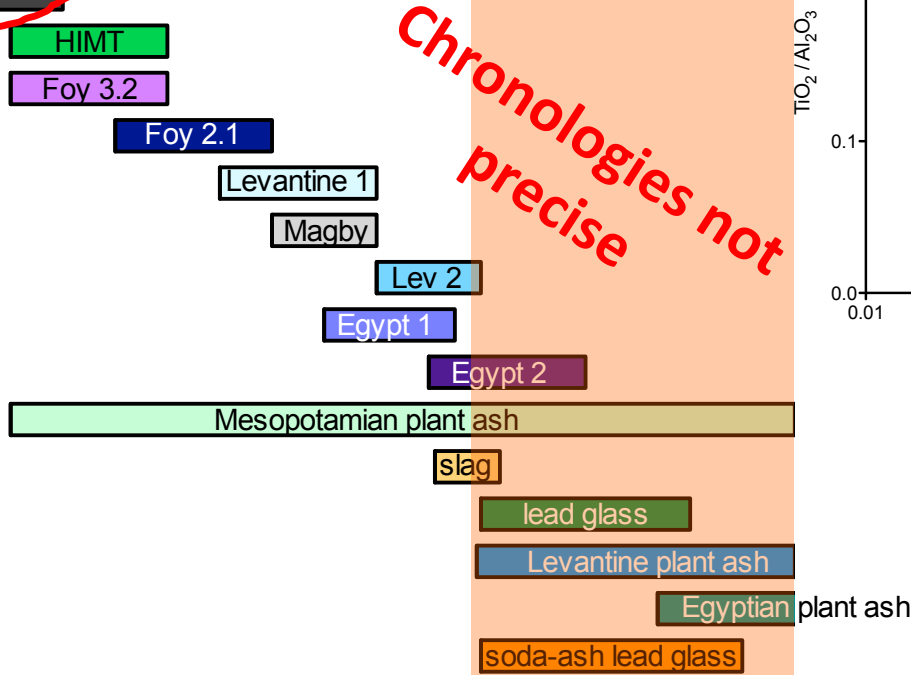


Distinct primary glass production groups

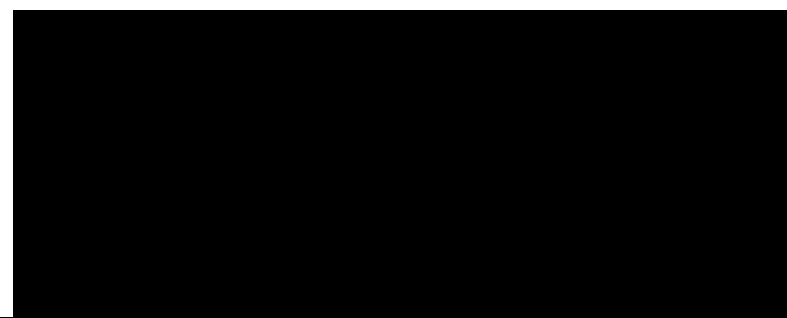
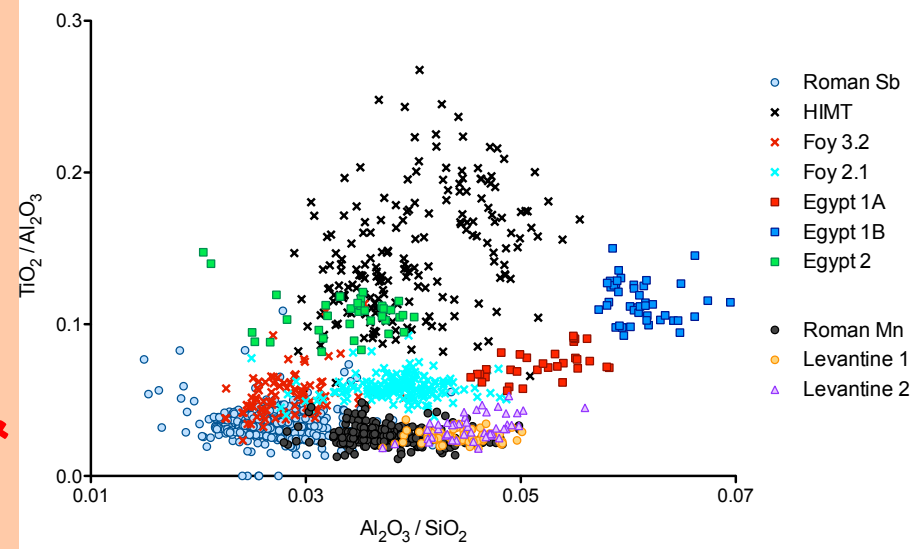


Natron glass

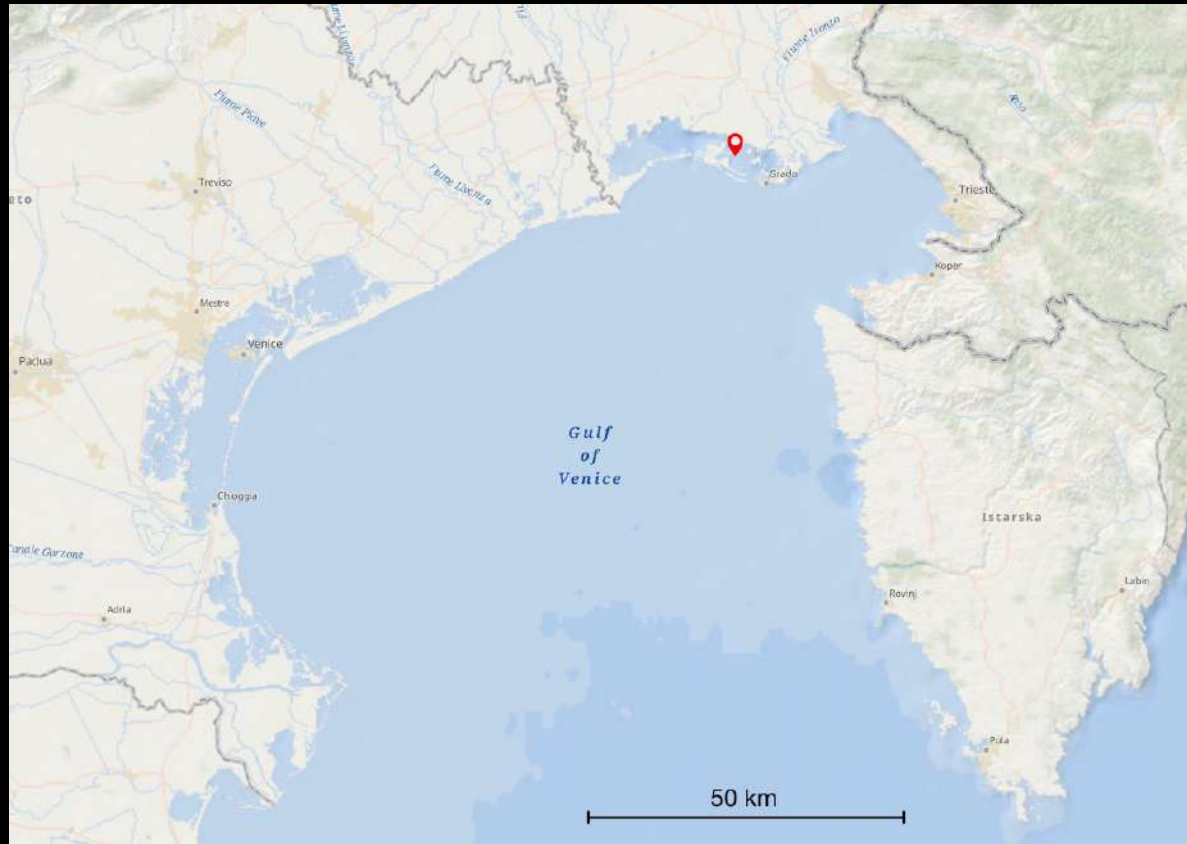
Plant ash & High Pb glass



Chronologies not precise

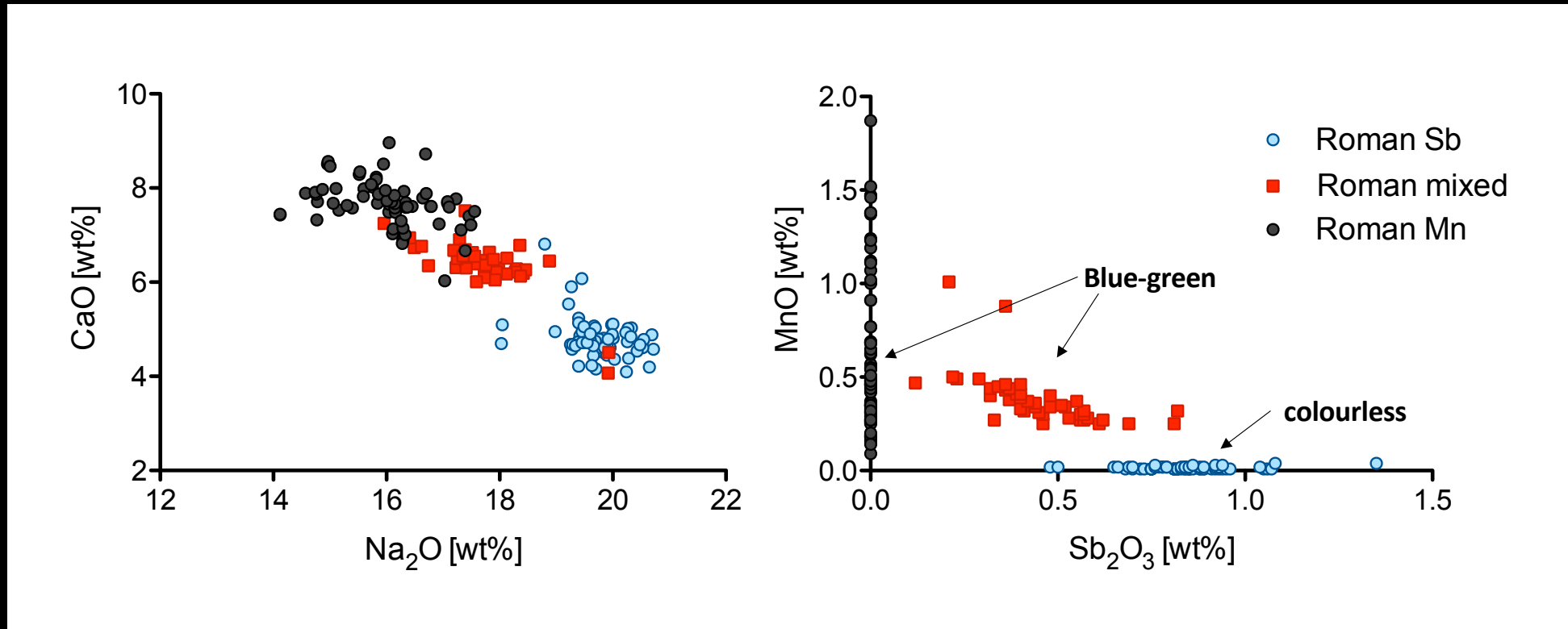


Iulia Felix – recycling in the Roman period



Iulia Felix shipwreck, first half of 2nd century CE
Hull of shipwreck in situ (Soprintendenza Archeologia Friuli-Venezia Giulia)
3D model of the hull and cargo in situ (Costa & Beltrame, 2021)

Mixed compositions – recycling in the Roman period



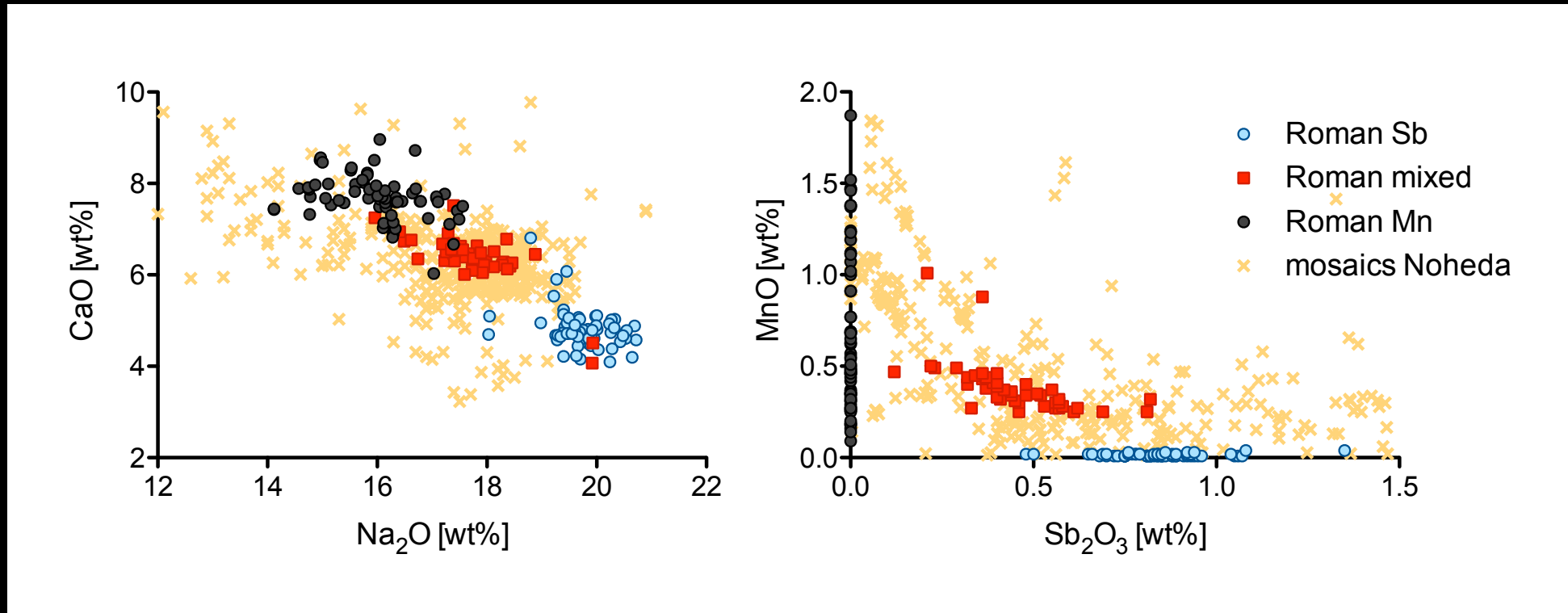
Data from Silvestri et al. (2008) and Silvestri (2008)

Barrel of about 140 kg of broken vessel glass

Colourless > 3,000 fragments

Weakly coloured (bluish, greenish, blue-green) > 6,000 fragments

Mosaic tesserae – recycling in the Roman period



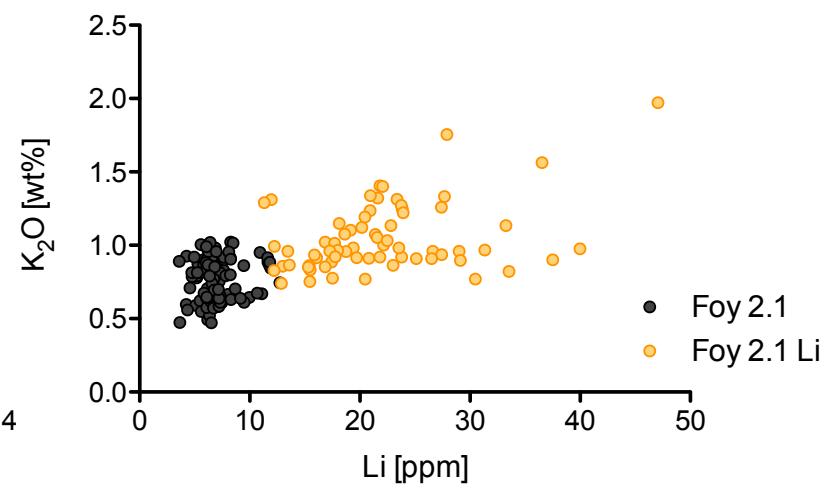
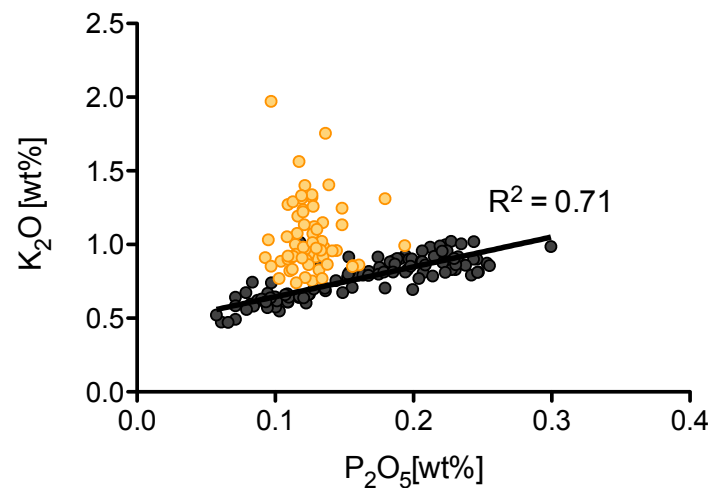
Noheda data from Schibille et al. (2020)

Mosaic tesserae – recycling in the Roman period



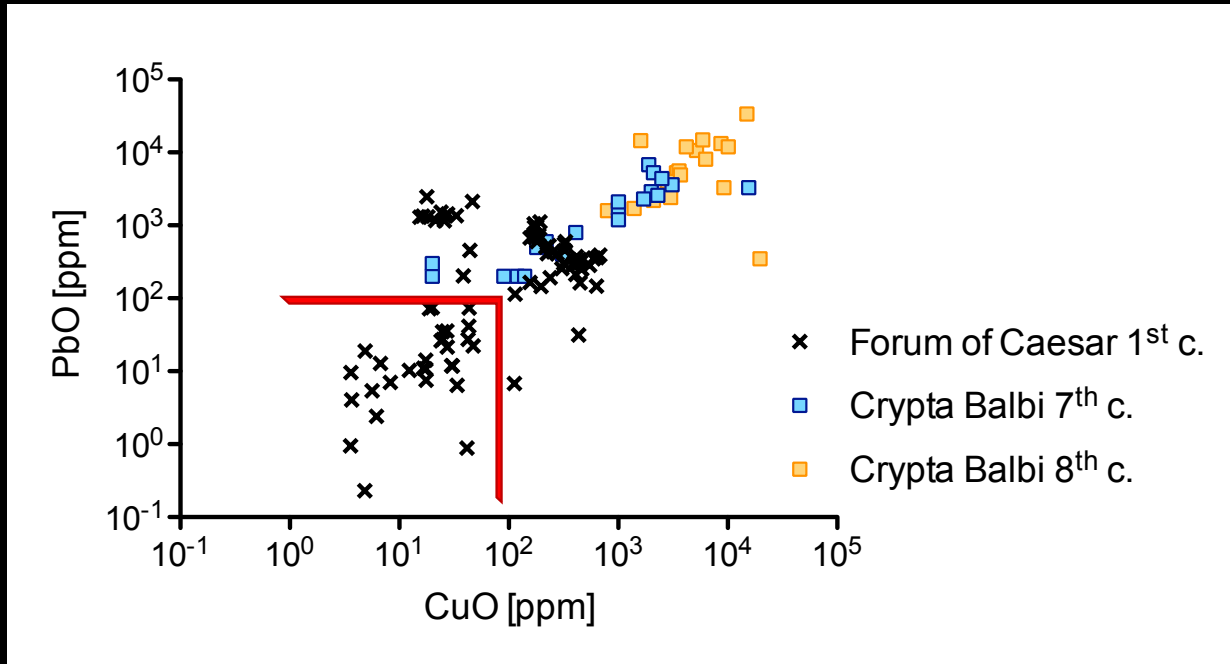
4th-century Roman Villa in Noheda (Spain), elaborate floor mosaic with large amount of glass tesserae

Accidental contamination – furnace environment / fuel ash



Schibille et al. (2022)

Accidental contamination – colourants & opacifiers



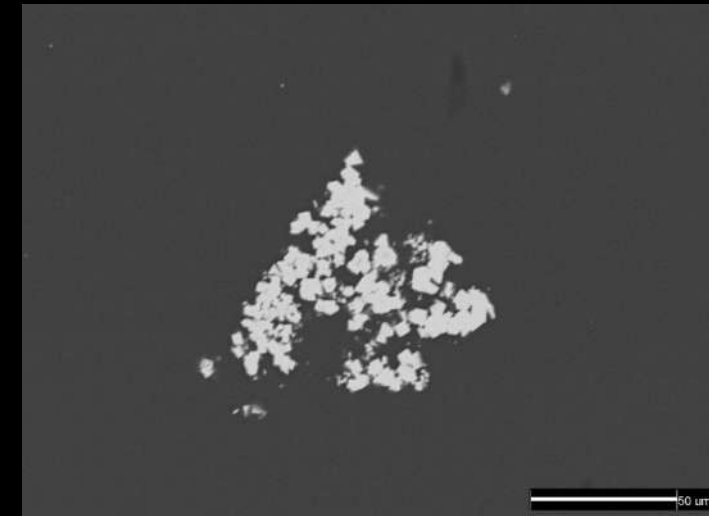
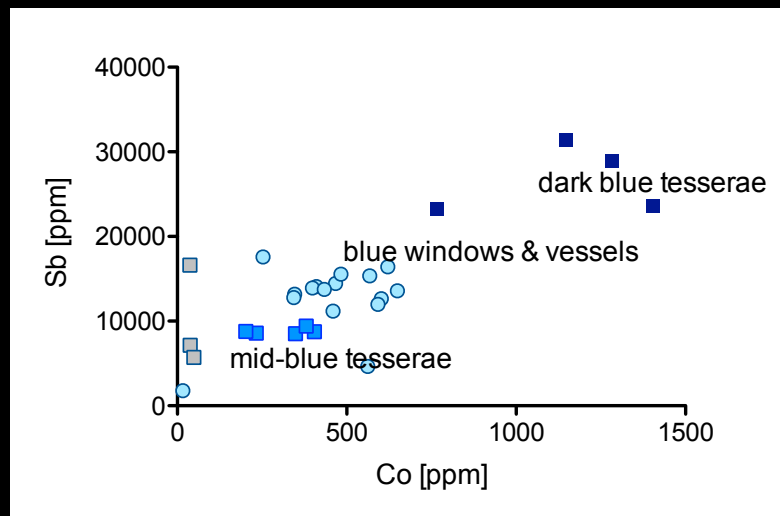
Increase of colourants and opacifiers
in otherwise uncoloured glass
above background levels of silica source

e.g. CuO or PbO > 100 ppm

**accidental incorporation of
coloured cullet (broken glass)**

Crypta Balbi data (Mirti et al. 2000 & 2001); Forum of Caesar (unpublished data)

Recycling in the early medieval period



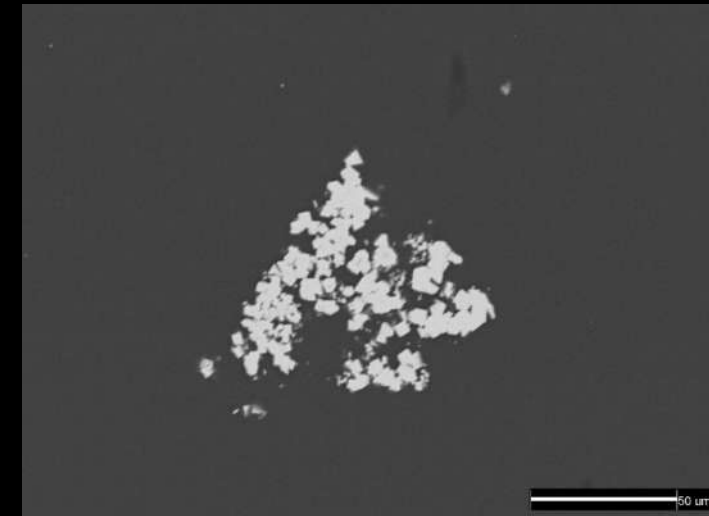
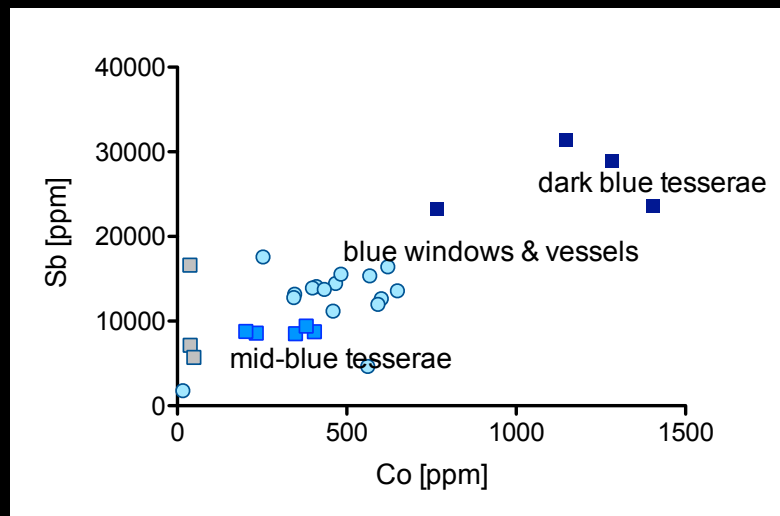
Schibille & Freestone (2013)

Schauss (2008), MSc, University of Cardiff



San Vincenzo al Volturno,
9th-century monastery in Southern Italy

Recycling in the early medieval period



Schibille & Freestone (2013)

Schauss (2008), MSc, University of Cardiff



San Vincenzo al Volturno,
9th-century monastery in Southern Italy

Recycling of mosaic tesserae from 1st – 3rd centuries

Cobalt blue tesserae were used to produce translucent blue window and vessel glass

Recycling in the early medieval period

Roman tesserae



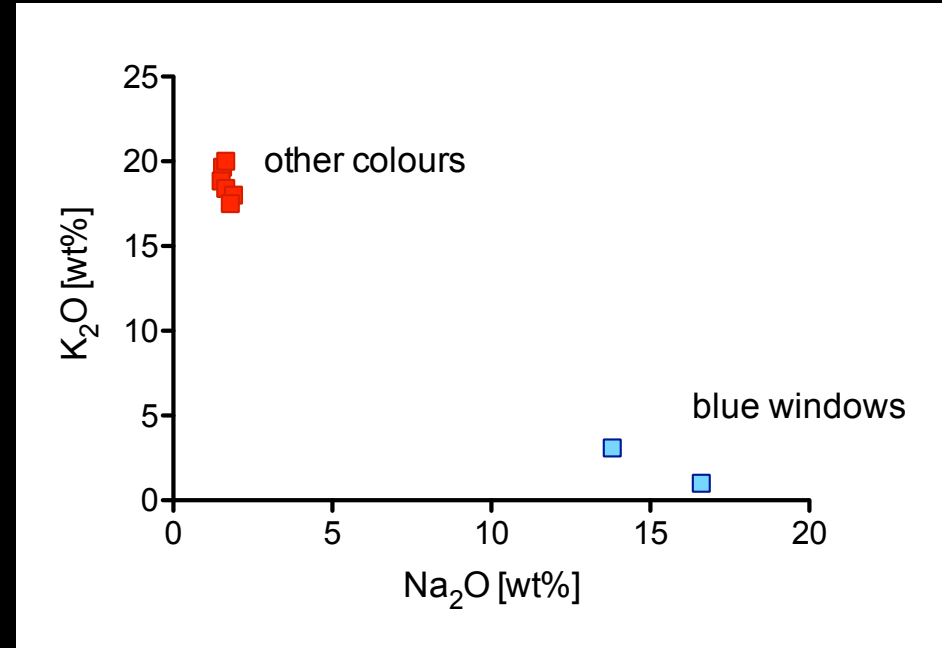
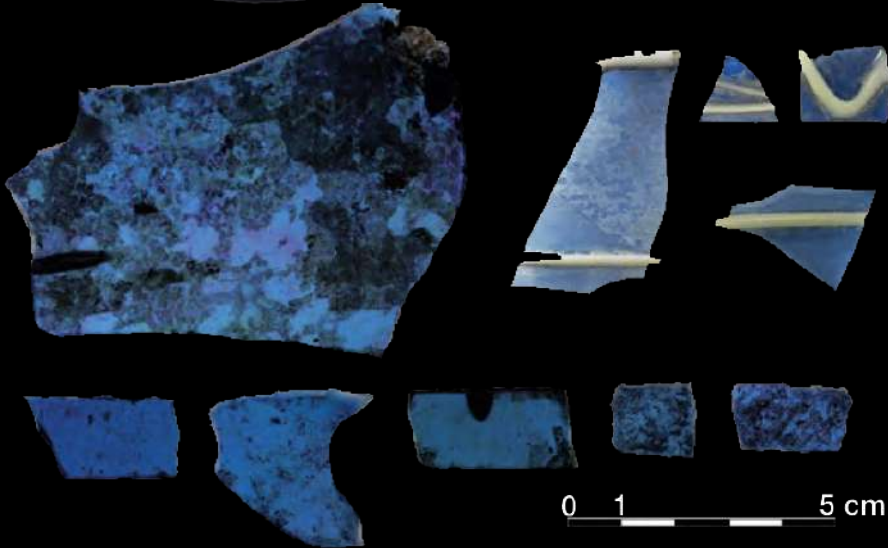
Carolingian windows



Recycling in the early medieval period



Reliquary Saint Savin, 11th century
© Alienor.org, Musées de la ville de Poitiers et de la Société des Antiquaires de l'Ouest



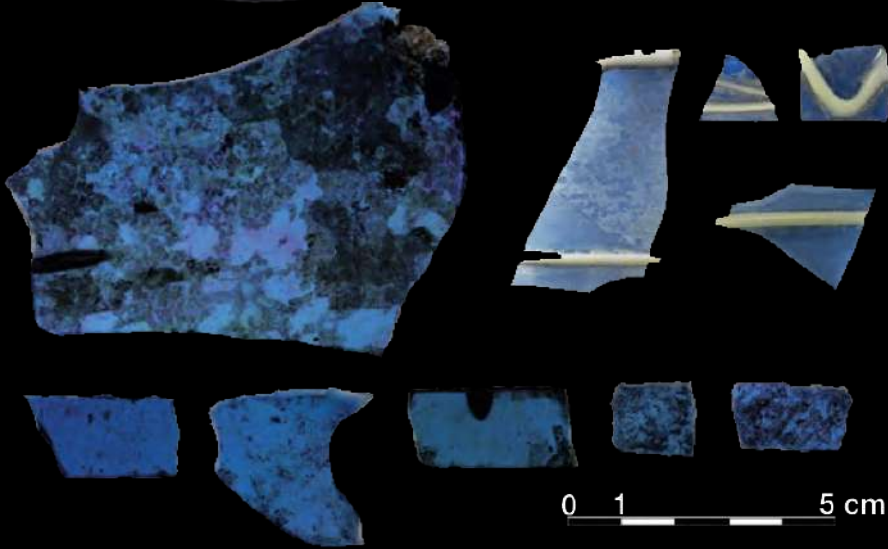
Window glass from the ancient cathedral in Nice (11th century), Pactat (2022)

Recycling in the early medieval period

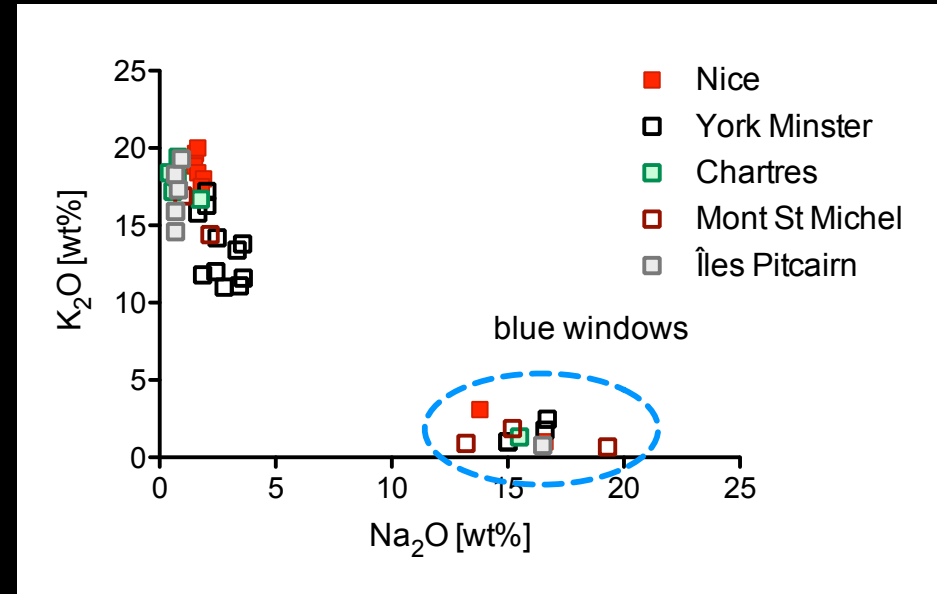


Reliquary Saint Savin, 11th century
© Alienor.org, Musées de la ville de Poitiers et de la Société des Antiquaires de l'Ouest

2 cm



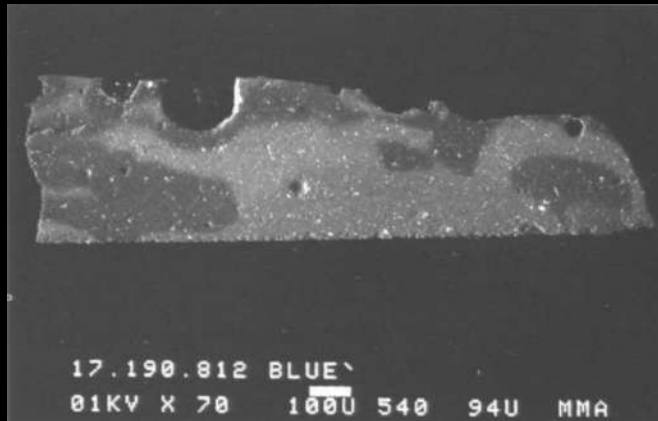
0 1 5 cm



Data from Brill (1999)

Window glass from the ancient cathedral in Nice (11th century), Pactat (2022)

Recycling in the early medieval period

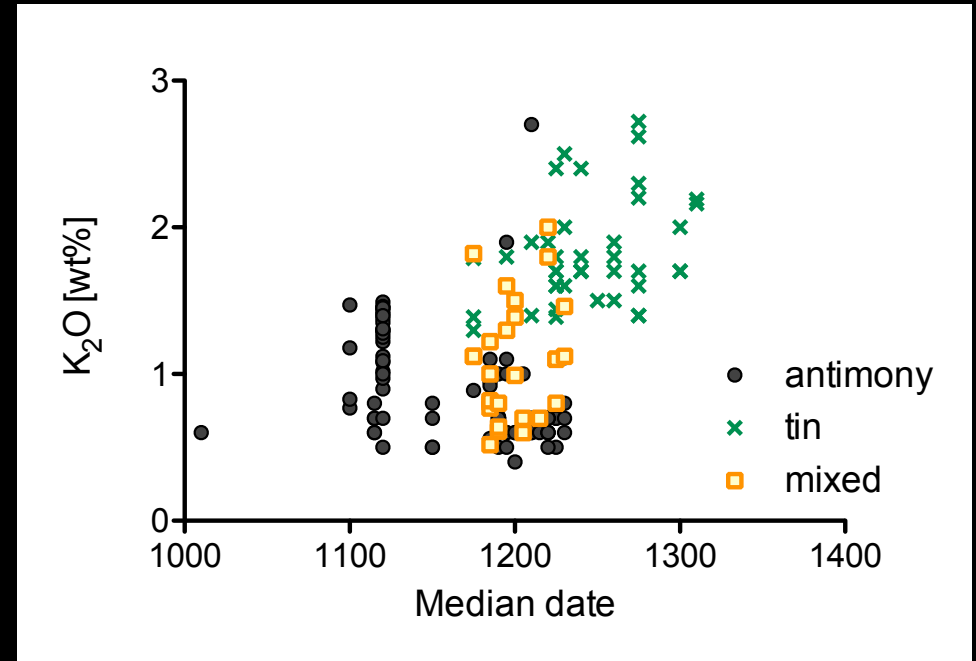


SEM image of opaque blue enamel, bright areas rich in Pb, with crystals of tin oxide, darker areas contain calcium antimonate and little Pb (Biron et al. 1996)



Saint Peter, Limoges ca. 1185-1200,
24.8 x 9.5 cm

© Metropolitan Museum of Art, NYC



Recycling in the early medieval period



XII. DE DIVERSIS VITRI COLORIBUS NON TRANSLUCIDIS

Inveniuntur in antiquis aedificiis paganorum in musivo opere diversa genera vitri, videlicet album, nigrum, viride, croceum, saphireum, rubicundum, purpureum; et non est perspicax, sed densum in modum marmoris, et sunt quasi lapilli quadri, ex quibus fiunt electra in auro, argento et cupro, de quibus in suo loco sufficienter dicemus.

Inveniuntur etiam vascula diversa eorundem colorum, quae colligunt Franci in hoc opere peritissimi, et saphireum quidem fundunt in furnis suis, addentes ei modicum vitri clari et albi, et faciunt inde tabulas saphiri pretiosas ac satis utiles in fenestris. Faciunt etiam ex purpura et viridi similia.

In the **ancient pagan buildings**, one finds in the **mosaic** work different types of glass, for example, white, black, green, saffron yellow, blue, red and purple; and the glass is not transparent, but opaque like marble. And they are, as it were, cube-shaped little stones, from which are made the enamels on gold, silver and copper, about which we shall speak

We also find various small vessels made of these colours, which are collected by the Franconians, who are very experienced in this technique. **They melt it in their furnaces, add a little clear colourless glass, and make valuable blue glass plates, which are well-suited for use as window panes.** They also make them (the window panes) from purple and green (glass).



Theophilus (1070-1125 CE), De Diversis Artibus

Textual evidence for glass recycling

Broken glass and its collection is mentioned in the literature in the 2nd half of the first century CE

Martial (*Epigrammata*), Statius (*Silvae*) & Juvenal (*Satires*) refer to the collection of broken glass and exchange for sulphur

Cassius Dio (ca. 165-235 CE) remarks that the emperor Claudius grants Roman citizenship as cheap as the value of broken glass

Price Edict of Diocletian (301 CE)

DIOCLETIAN'S *PRICES EDICT* 16.1-6

Line	Translation	Denarii
1a	Alexandrian glass, one pound	24
2	Judean greenish glass, one pound	13
3	Alexandrian glass cups and smooth vessels, one pound	30
4	Judean glass cups and smooth vessels, one pound	20
5	Window glass best (quality), one pound	8
6	[Window glass] second (quality), one pound	6



Archaeological evidence for glass recycling



Cullet dump from Roman London;
pile is ca. 0.4 m; © Historic England



Cullet retrieved from local workshop,
Augusta Raurica, Switzerland, 2nd to 3rd
centuries



Chunks of raw glass and cullet found in a
Byzantine glass workshop in Beth Shean,
Israel © Freestone

Archaeological evidence for glass recycling



Deposits of cullet (broken glass)

Military camps (e.g. Nijmegen, Guildhall Yard London, Alzey, Hambacher Forest)

Urban contexts (e.g. Augusta Raurica, Avenches, Trier, London, Sardis, Bet Shean)

Churches (Palaestina Salutaris / Tertia)

Shipwrecks (Iulia Felix, Serçe Limani)



Organisation and scale of recycling?



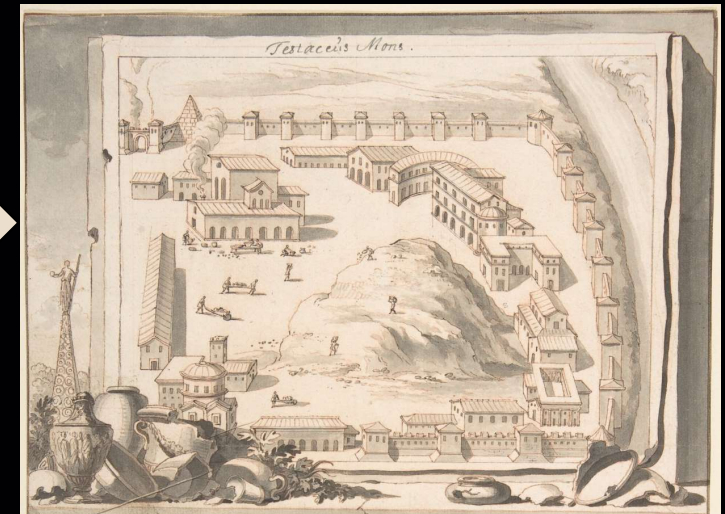
Broken glass from the Serçe Limani shipwreck, ca 1025 CE
© INA GW-1393, REF 4378

Organisation & socio-economic dimensions



- Recycling was ubiquitous and glass was exploited in every possible way since the 1st century CE
- Increase in recycling in late antiquity / early middle ages
- Local economy versus long-distance exchange
- Human agency
- Economic value of glass cullet

The cost of a glass vessel was between 10 and 20 times higher than that of a pottery vessel of equivalent size



What can we learn from the history of glass recycling?



- **Recognising of economic & technical value of recycling**

 - Independence of long-distance imports

 - Savings on fuel & decreasing production costs

 - Important source for colourants

- **Careful selection and separation of colours**

 - Recycling 'like with like' to avoid the glass properties to be 'muddied'

 - Unlimited (closed-loop) recycling

 - Reuse



Thank you!

**Thanks to all my colleagues at IRAMAT & collaborators
on the different projects!**

Special thanks go to Ian Freestone & Bernard Gratuze