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Track~~ing~~ Changes: New Methods for Assessing **Diachronic** Development in Ancient Italian Waterproofing Technology

Vitruvius
Try a pun title. People love them.

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The monumental water features of Roman Italy represent the greatest investment into water infrastructure known from antiquity. Enabling this unprecedentely complex hydraulic network were advances in waterproof mortar technology. Waterproof mortar linings prevented water-loss and, because of their smooth finish, greatly improved water flow rates. Although an essential aspect of ancient hydraulic infrastructure, few attempts have been made to track this technology's long-term development. In this research, 16 thin sections were created from the mortar linings of 15 water features in the Bay of Naples and Rome (Figure 1). These varied structures included nine aqueducts, three cisterns, two baths and a pool. They were dated between the 1st c. BCE – 4th c. CE. The study of these 15 spatially and temporally diverse linings allowed, for the first time, five centuries of innovations in ancient Italian waterproofing technology to be identified and tracked (Figure 2.)

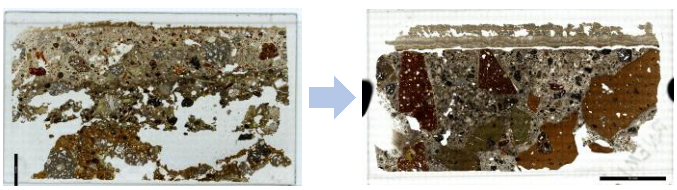


Figure 2. Two thin sections showing the change in mortar recipe between 1st century BCE Pompeii and 1st century CE Rome, 10cm scales.

Petrographic microscopy (PM), X-ray fluorescence microscopy (XFM) and digital image analysis (DIA) allowed the key attributes of each waterproof lining to be quantitatively and qualitatively described. This data was then used to discern spatial and temporal changes in ancient Italian lining technology. XFM was used to visualise the elemental composition of each lining and explore how the choice to use specific aggregates altered the function of different layers (Figure 3). PM was the primary instrument used to identify the constituents and binder features of each mortar (Figure 4). DIA, which included the randomised point counting function (n = 1000 points) in JMicroVision and the particle analysis function in ImageJ, allowed the size, roundness and area percentage of different constituents to be quantified (Figure 4). The combined use of multiple scientific analyses with a broad sampling strategy allowed several instances of technological change in to be identified and tracked.

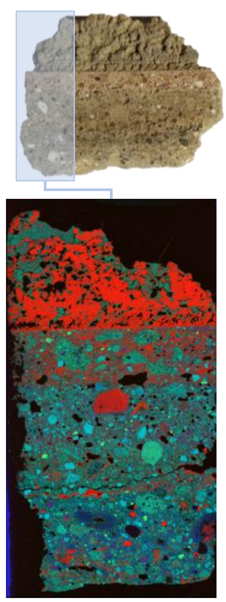
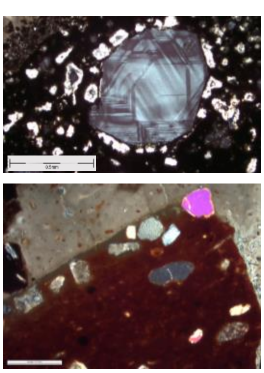


Figure 3. A mortar from the Aqua Augusta and the corresponding thin section scanned in XFM. Aluminium (Al), Calcium (Ca), Silicone (Si).



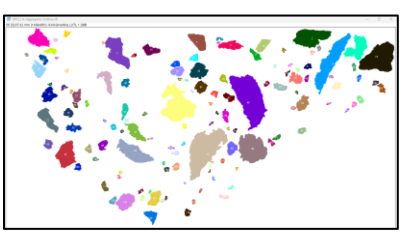


Figure 4. **Left**: Micrographs of two different aggregates used in ancient Italian mortars: Pozzolana Nere (a specific deposit of scoria) and crushed terracotta. Both images taken at 100x magnification, cross polarisation, 0.5mm scale. **Right**: Masks of terracotta aggregates in a mortar. These masks can be used within the ImageJ particle analyse function to calculate the size and roundness of different types of aggregates in a waterproof lining.

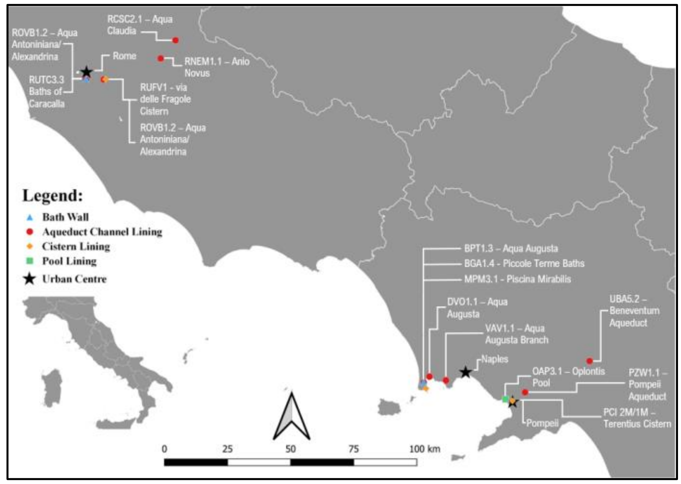


Figure 1. Map of the water features sample in the Bay of Naples and Rome.

It was found that crushed terracotta was mainly used in water interfacing (top) layers. 12 of the 16 water interfacing layers contained predominantly terracotta aggregate. This slower reacting material allowed the mortar surface to be thoroughly polished before it set, increasing flow rates and slowing travertine buildup (Seymour et al 2022). In contrast, preparatory (bottom) layers relied on fast reacting volcanic aggregates that reduced construction times (Lancaster 2021:8). Some aggregates were used for entirely aesthetic reasons. The linings of a pool and fountain at Oplontis Villa A used chips of marble for aggregate. Using marble had limited mechanical benefit but excelled at advertising the owner's wealth.

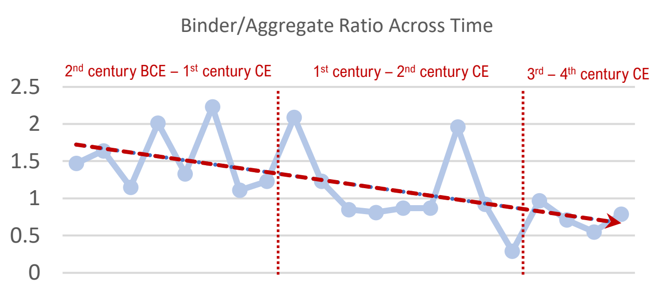


Figure 5. A line graph with trendline showing the decrease in binder/aggregate ratio through time.

DIA also found that the binder/aggregate ratio of the mortars decreased through time (Figure 5). The earliest samples had more binder than aggregate, but quickly, the amount of aggregate increased, until by the last period, all samples had a binder/aggregate ratio of <1. Increased amounts of aggregate improve the mechanical strength and durability of a mortar, meaning waterproofing technology improved over time in Roman Italy (Pavía and Toomey 2007). The additional aggregate needed for this improvement became available as the Roman economy and construction industry expanded during the Imperial period, highlighting how broader socio-economic factors influenced ancient technological innovation (DeLaine 2018). By combining scientific techniques and sampling broadly, this study was able to successfully track changes in ancient waterproofing technology. Further research will continue to expand these initial findings.

References

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