Changes in the technology of pottery production over about two millennia at Tayma (Saudi Arabia): an archaeometrical study

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Abstract
This study focuses on the archaeometric characterization of Bronze Age to Islamic Period pottery from the archaeological site of Tayma (North-western Saudi Arabia), with the main aim of defining the provenance, the production technology and its evolution over time. For this reason, both stratigraphically dated potsherds and clayey materials collected in the surroundings area of the archaeological site were analysed under petrographic, mineralogical, microstructural and chemical viewpoints and the analytical data were processed using multivariate statistical tools. Most of the pottery at Tayma was locally produced according to different recipes, which show a straight correlation with the age. This indicates a systematic change in the pottery production technology over the period of about two millennia here considered. The majority of the pottery is locally produced, and only few ceramic classes, mainly glazed ware, resulted to be imported from different Middle-Eastern regions.

Introduction
This research is part of a joined-project coordinated by the German Archaeological Institute of Berlin and involving the Saudi Arabian Department of Antiquity and the Department of Archaeology and Epigraphy of King Saud University (Riyadh). This project aims to study the material culture as well as the more classical archaeological aspects of Tayma, a site located in the Tabuk province (latitude 27° 37’ N, longitude 38° 28’ E) north-western Saudi Arabia. The importance of the archaeological site of Tayma is related to its almost continuous occupation throughout several millennia. The age of the material here considered is from the Late Bronze Age to the Islamic Period. The presence of an important aquifer and a palm grove determined the site to develop and to become a reference point in the trades within the Arabian Peninsula desert steppe area. Numerous attestations indicate that Tayma was involved into commercial and cultural exchanges with the Mediterranean, Mesopotamian, Egyptian and Southern Arabian Peninsula people (Avanzini, 1997, Eichmann et. al., 2006, Hausleiter, 2006). In this frame, the ceramic materials play an important role, since the local and regional stratigraphic sequences are based on the continuity versus discontinuity of their typology over time. Therefore, the archaeometrical analysis of the pottery at Tayma can supply important information both on the ceramic production technology as well as on the provenance, allowing the identification of cases of importation and/or local imitation. For this reason, 238 potsherds, 100 from a superficial survey and 138 from stratigraphic contexts dated between late Bronze Age and Early Islamic Period were studied and compared with a set of clayey and sandy materials collected from the surroundings of Tayma.

Methods
All the samples were studied in optical microscopy, in order to define homogeneous petrographic groups in terms of groundmass microstructure, textural features and composition of inclusions. The mineralogical and chemical composition of both potsherds from stratigraphic contests and geological clay samples were determined by X-ray diffraction (XRD) and X-ray fluorescence (XRF), in order to provide constraints to the definition of the firing temperature and possible provenance of the archaeological materials. A multivariate statistical approach was also adopted to process the analytical data with the main aim of distinguishing locally-made and imported objects, and defining the production recipes adopted over time. Detailed analysis of specific microstructures formed during the firing process were also analysed on selected samples in scanning electron microscopy.

Results and conclusion
On the basis of the minero-petrographic composition of inclusions and of the textural features of the ceramic pastes, 9 main petrographic groups were defined.
Group 1 is characterised by fine grained inclusions mostly made of quartz and sometimes siliciclastic sandstone and siltstone rock fragments. The same kind of inclusions was also identified in petrographic group 5, which is however characterized by coarser grained inclusions. Group 2 displays a fine-grained and quartz-poor matrix and bears rare inclusions mostly of argillaceous rock fragments (ARF). Group 3 shows coarse grained inclusions made of ARF, quartz grains and quartz-rich siltstone and sandstone rock fragments. Similar types of inclusions characterise also petrographic group 7, the groundmass of which is often vitrified. This group characteristically bears vitrified ARFs showing a bubble-rich texture caused by degassing during melting. Group 4 differs from the others for the presence of volcanic rock inclusions, while group 6 contains extremely coarse grained inclusions of quartz and feldspar. Although samples belonging to group 8 display under the optical microscope texture and type of inclusions similar to those of group 1, diffraction patterns show the presence in the matrix of gehlenite, suggesting the presence of carbonate in the original clayey material. Lastly, in group 9 groundmass is almost absent and inclusions are made of angular grains of quartz.

The minero-petrographic composition of inclusions in the majority of the groups (1, 2, 3, 5, 7) is consistent with the geology of the area surrounding Tayma, which consists of Palaeozoic sedimentary sequences, mainly represented by mudstones, sandstones, siltstones and occasionally limestones containing rare cherts (Le Nindre et al. 2003; Hussain 2007), associated to Quaternary deposits of sand, often forming large dune systems, and subordinated clays and evaporites. Samples belonging to group 4 are characterised by basalt inclusions, a rock type which is only outcropping at least one hundred kilometres far from Tayma, as well as those belonging to group 6, the inclusions of which derive from an alkaline granitoid rocks. Therefore on the basis of the mineralogical and lithological match, most of the ceramic pastes were probably locally produced according to different recipes, for which locally available tempers, mainly represented by sand, were added to a clay material. When potsherds are compared with the clay materials from the surrounding of Tayma in terms of chemical composition, it is clear that part of the pottery was imported. Statistical multivariate analysis carried out by the Principal Component Analysis (PCA), revealed that potsherds of groups 1, 2, 3, 5 and 7 form a unique and homogeneous group similar to the clay materials collected in the area, whereas all other groups (4, 6, 8, 9) are chemically not comparable with the clay materials of the area of Tayma, indicating that they were probably imported. Particularly interesting is the case of potsherds of group 9, which can find a petrographic and compositional correspondence with the pre-Islamic Egyptian Faience (Tite et al. 1983). Going into more detail on the local productions, the dendrogram of the cluster analysis (CA) and the score and loading plots of the PCA (Figure 1) indicate that potsherds group according to both petrographic composition and age. This evidence suggests that recipes for the pottery production, in terms of abundance and type of temper, and composition of the starting clayey materials, changed over time. Moreover, the statistical treatment of the chemical data identified specific trends of mixing between possible starting clayey materials and chemical composition of the temper, supplying an important tool to better describe tempering processes.

As for the firing technology, the mineralogical composition shows that all the potsherds locally produced contain mullite, spinel and quartz. This mineralogical assemblage indicates that the base-clay was kaolinitic in composition and firing temperatures around 1000°C (Aras 2004). This result is in agreement with the mineralogical composition of the clay materials collected from the surroundings of Tayma, composed of kaolinite and subordinate illite, interstratified clay minerals, quartz and goethite. Only samples of group 7, bear also hercynite and are hematite-free suggesting reducing conditions during firing and temperatures exceeding 1000°C (Letsch & Noll, 1983). The mineralogical assemblage of the imported potsherds is very different, since they contain gehlenite and diopside, indicating that a calcareous base-clay was used for their production and that firing was run at temperature above 850°C (Riccardi et. al., 1999).

When considering the evolution of the production recipes over time, some interesting points arise. Late Bronze to Early Iron Age potsherds mostly belong to petrographic group 1, whereas Hellenistic potsherds entirely belong to group 3. This indicates that during these period the production technology was very standardised in terms of production recipes. A very different situation is attested for the Middle to Late Iron Age pottery, which is characterised by a variety of petrographic groups differing in terms of
type of inclusions and base-clay. Finally, the Hellenistic to Early Islamic pottery spread over different petrographic groups, which are differentiated for the abundance of the different inclusion types. Therefore, these differences can be related to the use of different raw materials but in the frame of a standardized production technology.

This archaeometrical study permitted to define some important features for distinguishing the pottery production over time, supplying a new tool for interpreting the ceramic technological evolution at Tayma.

![Figure 1: Score plot (above) and loading plot (below) obtained by the PCA of the chemical data, showing the variation of the production recipes over time and the correlation with the weights of the different variables represented by the chemical elements. BA: Bronze Age, IA: Iron Age.](image)

References


SUMMARY LAST YEAR’S ACTIVITY

Courses:


GABRIEL WALTON: “Corso di Inglese scientifico”. Dipartimento di Geoscienze, Università degli Studi di Padova, 2008


FLORIS; “Introduction to GIS Techniques”, Dipartimento di Geoscienze, Università degli Studi di Padova, 2008.

Posters:

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Publications: