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Iron Age hydraulic plaster from Tell es-Safi/Gath, Israel

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ABSTRACT

Hydraulic plasters or mortars prior to the Roman period are rare. Here, we report the identification and characterization of 3000 year old (Iron Age) hydraulic plaster surfaces from the site of Tell es-Safi/Gath. This site, located in central Israel, was occupied almost continuously from prehistoric through modern times, and is identified as the Canaanite and Philistine city of Gath. A survey using an on-site Fourier transform infrared spectrometer (FTIR) identified the presence of amorphous silicates, in addition to calcite, in each of two superimposed plaster layers. This suite of minerals is characteristic of hydraulic plaster. An in-depth characterization of the plasters using FTIR, acid dissolution, X-ray fluorescence (XRF), X-ray powder diffractometry (pXRD), heating experiments and scanning electron microscopy (SEM) coupled with energy dispersive spectroscopy (SEM–EDS), shows that special silicate-containing minerals were brought from some distance to the site in order to produce these plaster surfaces. We therefore conclude that the plasters were deliberately produced, and were not the result of a fortuitous addition of local silicate minerals. A layer of around 150 μm thick enriched in carbonate hydroxylapatite was found in both plaster surfaces, and the same mineral was identified by infrared spectrometry in the surrounding sediments. This suggests that organic materials were used on these surfaces. These surfaces are among the oldest hydraulic plasters known.

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1. Introduction

Lime plaster was developed at least 15,000 years ago during the Natufian period and was extensively used during the Neolithic in the Near East (Gourdin and Kingery, 1975; Kingery et al., 1988; Wright, 2000, 2005; Valla et al., 2007). Since its invention, the basic preparation methods remained unchanged. Calcite, usually in the form of limestone, is heated to around 800 °C. This causes the release of carbon dioxide in a process known as ‘calcination’, and the production of calcium oxide (CaO, ‘quicklime’). The quicklime is not stable and readily hydrates to form calcium hydroxide ($Ca(OH)_2$, slaked lime or portlandite). The latter absorbs carbon dioxide from the atmosphere and calcite is reformed. During the drying process, the plaster hardens.

A second type of plaster, which can harden under water, is called ‘hydraulic plaster’. Hydraulic plaster is obtained when slaked lime is mixed with highly disordered silicate minerals. The Romans used volcanic ash from the area of Pozzuoli (ancient Puteoli) in the Bay of Naples, and hence this class of additives is known as ‘pozzolanic additives’ (Borrelli, 1999). This plaster was first documented in Classical-period Greece (5th to 4th centuries BCE), and was widely used by the Romans, from the 2nd century BCE onwards, and in post-Roman periods (Ward-Perkins, 1981, 97–120). Its ability to set under water enabled the building of harbors and bridges. A description of hydraulic plaster preparation using pozzolanic additives was written by Vitruvius (De Architectura 2.6), some 2000 years ago.

The origin and early development of hydraulic plaster technology is obscure. One reason is the manner in which these materials are described and analyzed. Several studies report pre-Roman “hydraulic” plasters, but these identifications are problematic, particularly since most of them lack a proper description and analysis of physicochemical properties of these materials, and others refer to materials different from true hydraulic plaster. One

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such case is the so-called 'white ware' vessels from Tell Ramad (Syria) from 5900 BCE (Gourdin and Kingery, 1975). No supporting evidence for a pozzolanic reaction was provided (Kingery et al., 1988). An even older plaster sculpture from the Pre-Pottery Neolithic Jericho (ca. 7000–6000 BCE) was described as having a 'limy clay' binder (Kingery et al., 1988). A plastered floor from Kommos, Crete, dated to the Middle Minoan III period (17th century BCE), was analysed and described as 'cement with a very high hydraulicity' (Dandrau and Dubernet, 2006). However, the authors suggest that the builders used marl (limestone with 35–65% clay) as their calcite source mainly because of its natural abundance locally and not specifically because of its physicochemical properties. The excavators at Phaistos applied the terms "calcestruzzo" or "astráki" to a type of cement described as "slightly hydraulic" and composed of stones, clay, lime, crushed potsherds, and sometimes whole pots (Fiandra, 1961–1962: 123, 125–126; Levi, 1964: 3–4). It was used to create a platform covering the remains of the "First Palace" prior to the construction of the "Second Palace" in Middle Minoan III/Late Minoan IA (ca. 1700 BCE; see Shaw, 1971: 222–223 with references; Walberg, 2001: 13). Chiotis et al. (2001) analyzed Mycenaean mortars and waterproofing plasters on the Greek mainland. The samples included plasters from cisterns of the citadel at Mycenae and at the Argive Heraion, and the floor of the courtyard in the palace of Tiryns. The plasters consist of an undercoat made of one or two successive layers, covered by a thin superficial lining, either homogeneous or stratified, composed of two layers. A siliceous lining was found in all three samples, together with some calcite, gypsum and clay minerals. The undercoats from Tiryns and Heraion are composed of lime with fragments and powdered terracotta, which can function as a pozzolanic material. This study indicates that hydraulic plaster was used during the time period of the Aegean civilization, providing chronological continuity in the Minoan and Mycenaean periods in the Aegean. The Mycenaean adaptation of Minoan building technologies has been thoroughly studied (for example, Wright, 1978), and it is highly likely that plaster technology was transmitted elsewhere. Furlan and Bissegger (1975) described lime mortars containing crushed ceramics from the 10th century BCE from Jerusalem. Some samples of wall plaster from the Iron Age II Tall Jawa contained silicate inclusions, but their composition or source were not fully determined (Hancock, 2003: 459–460).

The rarity of reports on pre-Roman hydraulic plasters can be due to the possibility that this plaster type was not widely used, or because they were not properly identified, or both. Hydraulic plaster cannot be identified only by visual inspection. A laboratory analysis is required.

We present here the identification and detailed analysis of two superimposed hydraulic plaster surfaces from Tell es-Safi/Gath. Tell es-Safi/Gath is a 50 ha mound in central Israel (Fig. 1), identified as the Canaanite and Philistine city of Gath (Maeir, 2008). The site has been excavated regularly since 1996 by the Tell es-Safi/Gath Archaeological Project of the Institute of Archaeology, Bar-Ilan University, directed by A.M. Maeir. The site was settled almost continuously from the Chalcolithic period till modern times, with several occupation peaks, one of which is during the Iron Age (12th to 8th centuries BCE). Several Iron Age strata were uncovered, representing most of the developmental stages of the Philistine material culture.

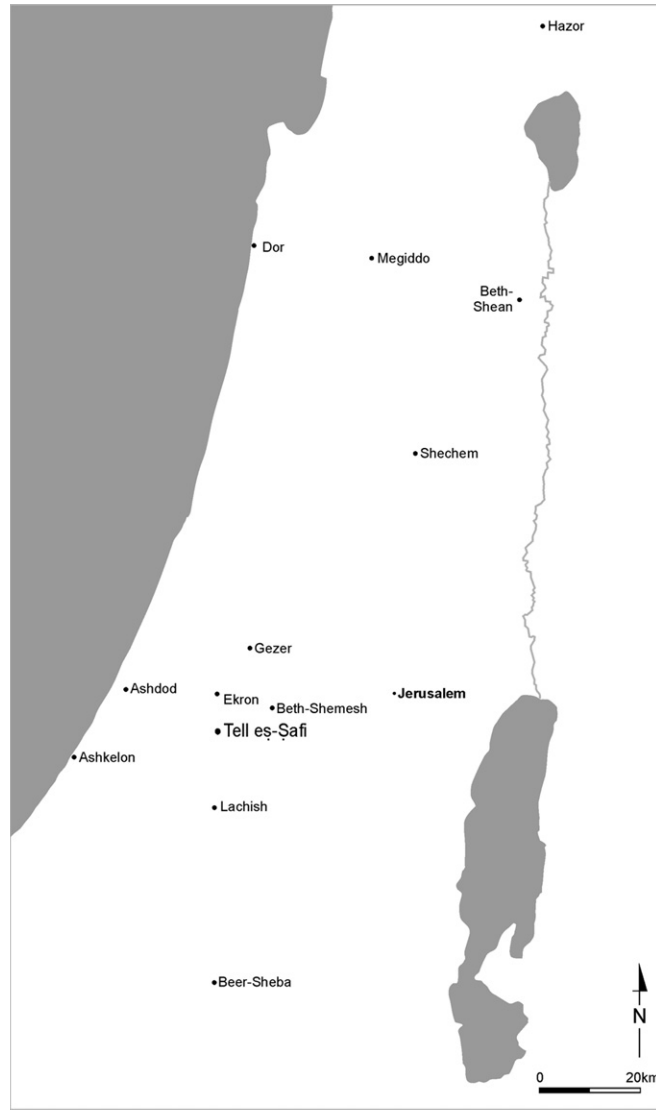

Fig. 1. Map of Israel with location of Tell es-Safi/Gath and major Iron Age sites.

2. Materials and methods

2.1. Archaeological context and description

Two plaster surfaces with a combined thickness of about 20 cm, were found in Area A, in square 223/80C (Fig. 2a). The surfaces were located in the north-western corner of the square, without any clear structural relations to adjacent features (Fig. 2b). Although all the edges of the surfaces are eroded or cut, and their original extent is unknown, the top of both surfaces were smooth and flat; an effect that might be achieved by means of a stone float (Shaw, 1971, 210, Fig. 238, 214). The measurements of the irregularly shaped preserved patch are ca. 120×75 cm. The series of preparation layers below the lower surface (L122036) indicates that more care and attention was paid to the construction of the lower surface than the upper surface. The base of the lower surface is composed of two layers of cobbles. The uppermost one (L122039), consists of approximately one hundred cobbles each measuring 6–10 cm, and the lower one was left in situ and was partially exposed. This was overlaid by a 5 cm thick layer of dark brown heavy clay (L122038), that was not exposed to elevated temperatures based on its infrared spectrum (Berna et al., 2007). An additional preparation layer, around 5 cm thick, was laid down on the clay layer (L122036, 2nd layer). This layer has a similar composition to the overlying plaster surfaces. However, in contrast to the surfaces, this layer is fragile and contains a very large amount of water-worn mollusk shell fragments (under 1 cm in size, averaging 7 mm). In addition, several hard usually black colored porous pieces, around 5 cm in

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