“Glazed Bricks in the Achaemenid Period”, (in German and English), Persien Antike Pracht, with contribution by M...

Shahrokh Razmjou

Glazed Bricks in the Achaemenid Period

Shahrokh Razmjou
With contributions by Mike S. Tite & A. J. Shortland and Marion Jung & Andreas Hauptmann

Glazed bricks are an important element in Achaemenid royal art and architecture. According archaeological evidence this technique was widely used from the beginning of the reign of Darius the Great, about late 6th century BC.

The main centres of Achaemenid period like Susa, Persepolis and Babylon started to use glazed bricks for new structures and buildings. Nowadays we may suggest that producing glazed bricks in Achaemenid period begun at Susa and then spread to Persepolis. Susa received the main concentration for creating glazed panels to adorn walls with polychrome glazed bricks.

Basically Darius re-activated Susa, the ancient Elamite capital by rebuilding the city that was damaged by Assyrian soldiers under Assurbanipal in the 7th century BC. The ancient royal city was not only revived by Darius, but after erecting the royal centre it acquired more than its lost glory and became one of the main centres of the Achaemenid vast empire.

With a strong governmental and financial support, a large number of the best known artisans from all corners of the Persian domain including different countries under the Achaemenid Empire, gathered in Susa and started to use their skills in an universal collaboration[1]. When a certain amount of the work was finished at Susa, some of the artists might have moved shortly afterwards from Susa to Persepolis and used their skills to create the most glorious structures of the empire bearing glazed friezes.

The first archaeological excavations at Susa were started by Jean and Marcel Dieulafoy in the late 19th century in which a large number of glazed bricks were found (Potts 1999, 330).

The recovery and study of Susa glazed bricks continued until today. Unfortunately almost the great amount of the collection was not found in their original location but they have been reused in other structures in later periods (Caubet 1992, 224). But some other fragments were found in the area where they have been fallen, like the courtyard or the north wall of the eastern court (Caubet 1992, 224). Later the excavations by Erich Schmidt at Persepolis gave another clear evidence for the beauty of the Achaemenid palaces in which the glazed bricks had decorated the walls (Fig. 1).

The Wall Decorations

Darius has left a foundation inscription at Susa and he has described his architectural activities in that text. In this inscription after he mentions Babylonians who wrought the baked brick, he refers to the Medes and Egyptians who adorned the wall which means they made wall decorations (Kent 1953, 144; Potts 1999, 328). If Darius did not mean the glazed bricks which were a masterpiece in his royal palaces, therefore there would be a missing part in Darius text for the important decoration of the walls (Fig. 2). On the other hand the glazed bricks actually are to adorn walls and they are a wall decoration in its complete meaning.

In his inscription first Darius refers to Babylonians who made (baked) brick and just after that he speaks about those who adorned the wall. To show the procedure in his inscription he mentions every work in turn and what he refers to, likely is the process of making wall decoration with glazed bricks. Also we have to remember that the glazed bricks are the only architectural element that needed to be baked and the rest of the buildings and palaces were made of mud-brick.

Another proof for supporting this idea can be found by the study of artistic styles of the images on the glazed bricks. Darius speaks about Egyptian artists who adorned the wall, we can clearly find some elements, which have been drawn in Egyptian style. Basically the images in glazed bricks, especially human figures are designed by the order and instructions of Persian royal designers as a basic model. In general the whole design seems to be melted in a unique style, but in some cases by analysing details we can come

across specific artistic elements. In the drawing of some motives, although they look very much Persian, the Egyptian drawing style can be recognised. For example a winged disc is very much like the representation of the Egyptian god Horus as a winged disc[2]. This artistic style is amalgamated with another artistic element that perhaps could be Median, as mentioned by Darius. These different styles together represent a Persian royal fashion design.

Susa friezes are also parallel to Achaemenid stone reliefs at Persepolis. Stone reliefs are actually decorating the walls of the palaces and thus they can be recognised as wall decorations. At Persepolis some images were chosen to decorate the walls of the palaces but in stone, and in Susa the images are parallel to those at Persepolis.

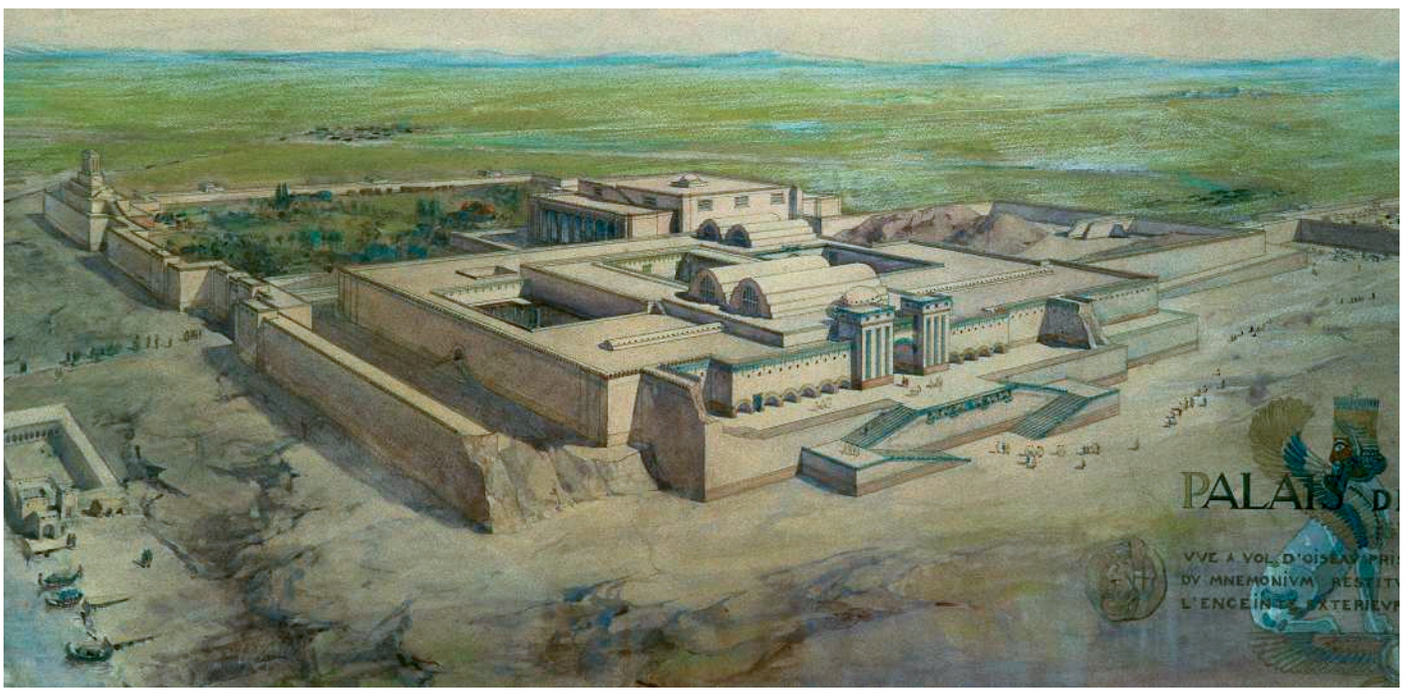
Historical Background

During archaeological excavations at Dur-Untashi, modern Chogha Zanbil, some examples of glazed bricks from Middle Elamite period were found by R. Ghirshman (1966, 110-111). They are decorated and painted on one peripheral surface and being glazed and used on the walls. These bricks, like inscribed bricks, could make a continuous chain of circles like a belt around architectural features at Chogha Zanbil. There were also other examples like glazed decorative pegs with inlays made of glass paste in the shape of a round eye[3]. The pegs usually were glazed with a green-blue colour glaze. At the same time in Chogha Zanbil, a similar glaze was also applied for statues like the statue of a sacred bull (Ghirshman 1966, 49-50, pl. XXXIII-XXXIV).

In the Middle Elamite period at Susa, moulded un-glazed bricks are more common, but very much like the Achaemenid period, each brick is a part of a complete scene. After that period, the same tradition re-appeared in Neo-Elamite period (Heim 1992, 206), but still no archaeological evidence has yet been found to confirm the continuity of the old manufacturing technique to Neo-Elamite period and then to Achaemenid period (Haerinck 1973, 118 f.). Perhaps the same tradition was followed in other parts of Elamite territory after the fall of the centres, such as Susa and Chogha Zanbil. But main reason is the lack of excavations to confirm the exact situation. Some examples found in Susa, including a polychrome glazed plaque, which was found with coloured rosette knob as an attachment of these plaques to the wall (Heim 1992, 207).

There is evidence from the Iron Age for use of painted bricks that can also be recognised as tiles. From the Median site of Baba Jan a number of monochrome painted tile-shape bricks were found (Goff 1969, 128f.). Other examples have been discovered from other Iron Age sites such as Ziwiye, Hasanlu and Bukan (Malekzadeh 2001, 138). In Bukan they represent polychrome designs including images of animals and mythical creatures.

Fig. 1: Susa; the palace of Darius. Water colour by Maurice Pillet (1881-1904; Chevalier 1997, Pl. VIII).



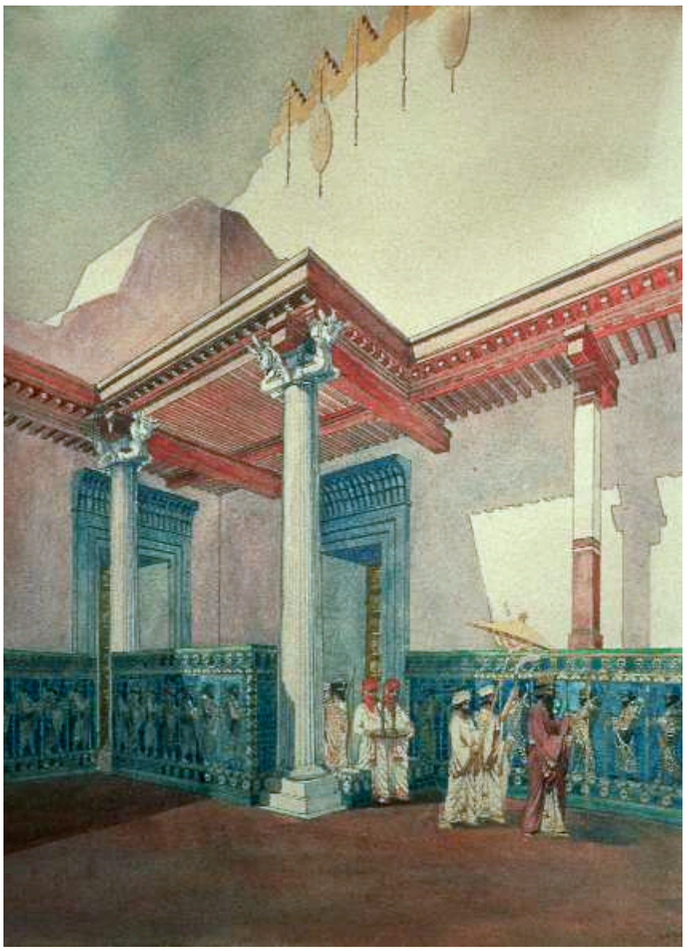


Fig. 2: Susa the palace of Darius: reconstruction of the base with the frieze of the guards at the forecourt. Water colour by Maurice Pillet (1881-1904); Chevalier 1997, Pl. XII.

In Neo-Babylonian period many glazed bricks were produced to adorn walls. The Babylonian glazed bricks were found at the Ishtar Gate and the palatial structures with the images of walking animals.

In Achaemenid period the usage of glazed bricks reached to its peak, both in technique and the design. The glazed friezes first appeared at Susa, perhaps by the instructions of designers and engineers of Darius as a decorating element for new royal palaces.

Comparison of Susa and Persepolis

Basically Susa is located in an area without stone resources. For constructing the royal buildings of Susa, Darius has imported stone for the columns from a village called Abiradush (DSf: Kent 1953, 144). Therefore stone was not an economical and reasonable material to be used for decorating the walls and representing the royal reliefs at Susa. Therefore Achaemenid designers at the royal palaces of Susa preferred to use glazed and un-glazed bricks to decorate the walls.

But unlike Susa, Persepolis was built on a rocky bed and laid back to a limestone mountain with access to many stone resources in the region. Therefore the designers could use plenty of stone carvings instead of glazed bricks. At Persepolis glazed bricks were also used but in lesser extent. Susa was built with more glazed bricks and lesser stones, and Persepolis was made with stone and lesser-used glazed bricks. After receiving paint the stone reliefs could become like the glazed bricks with a similar function (Frankfort 1954, 267). But of course they were probably not as shiny as the glazed bricks.

The glazed bricks are also different in style. At Susa there are many fragments that represent human and animal figures.

The human figures include the images of the so-called Susian soldiers and of course Royal images (Canby 1979, 315-320, Plate 50). There are also images of individuals carrying things ascending the staircase of the palaces. There are also some other miscellaneous fragments showing other individuals like a wreathed man (Muscarella 1992, 238, fig.166).

At Susa many other fragments were found representing animals and mythological or symbolic beings. At Persepolis there is no evidence of a human or animal representation on glazed bricks. But the same iconography can be found on stone.

Material, Shapes and Variations

A huge number of glazed bricks at Susa and all the glazed bricks from Persepolis are siliceous bricks with a mixture of sand and lime that have been fired up to three times for making the brick, its painting and glaze (Caubet 1992, 223; Haerinck 1997, 30). Achaemenid bricks from Babylon are also made from the same material (Haerinck 1973, 118) and other bricks from Borsippa (more seem to be Achaemenid than Neo-Babylonian) are clay baked bricks (Reade 1986, 110, pl. 15a-b). Usually the designs on the glazed bricks are outlined with a black paste and then they received the rest of the paint and the glaze. Probably the bricks had a preliminary coating on their surface.

They were produced in different shapes due to their function. For forming a panel with a number of bricks, the architects needed to use mortar and sometimes asphalt, to join the bricks. Because each brick is a part of a scene and the fragments had to join together closely, if mortar was applied then a gap was made between the bricks and the scene would stretch. Also without mortar, the wall could not be erected. For solving this problem, the upper surface of each brick was made in a wedged shape with a slipped surface

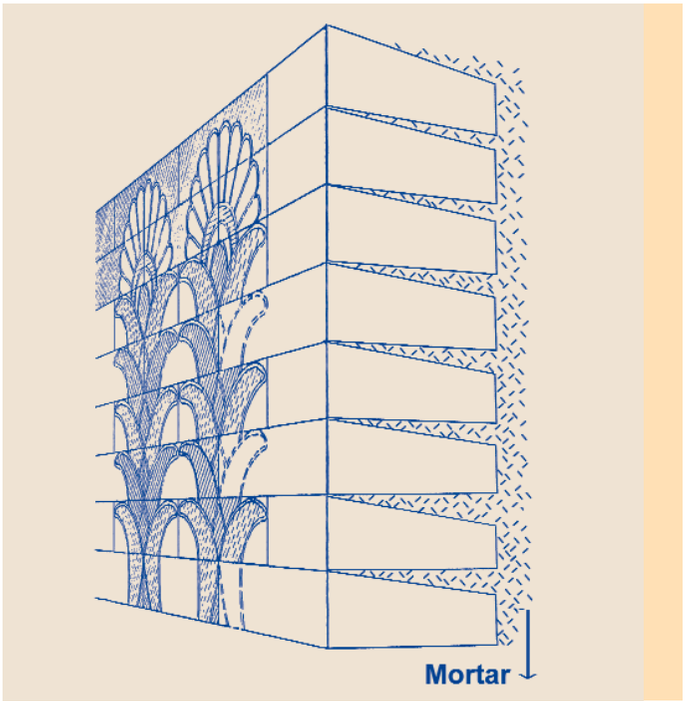


Fig. 3: A section of a glazed brick frieze with a provided space for mortar; drawing by Sh. Razmjou.

on the top. Then the outside edges of each brick could join to other brick and in behind there was enough space, provided for the mortar (Fig. 3). But in the case of other bricks like some inscribed bricks, there was no need to do so. Because each of those was a separate register and they could have a thin layer of mortar in between and also on the facade. Therefore they were made in a normal rectangular shape of a brick.

Some other forms of glazed bricks were produced as a pavement or as top of stepped-shape parapets that had four decorated lateral sides. These types of bricks were attached only with their lower surface.

Place of Their Usage

Because the glazed bricks at Susa might have been used in a lower level on the palace walls, they have to be designed from the beginning of designing the palace. They are not ornaments but they are clearly bricks that were placed in the wall.

According to excavators at Persepolis, such as Schmidt, the broken fragments of glazed bricks were found in the area between the southeast tower of the Apadana palace and the northwest of the Tripylon Gate (Schmidt 1953, 77-78). Scholars thought they might be the decorating façade of the Apadana towers at the top and they were scattered in that area after the collapse of the tower (Schmidt 1953, 78). Persepolis is located in a mountain region and still receives huge amount of rain and snow every year starting from the autumn. The size of the water channels of the Persepolis palaces shows that they have been designed to flow away a huge amount of water from the roof. But some would think if glazed bricks were used outside a building on the façade, they would apparently have received damage after few times of raining. Because they are decorative architectural elements and were designed to be used in the structure, they could easily damage the whole building and could not resist much against the water. This is caused by a different climate comparing to Babylon. But mud-bricks were also used for the walls and they could have the same problem. Therefore we should think about a strong mortar or a strong covering material for mud-brick façade, which could resist such condition. But the glazed bricks could stand with their glaze against the rain and protect the colours and the wall.

From the other point of view glazed bricks were not used for an internal space of towers, since they could have a minimum view. The size of drawing lines shows that they were designed to be visible from a distance. By considering all these facts we may suggest that possibly the glazed bricks might have been used on the façade of the towers, both outside and under the portico which was a roofed and covered area and was also more protected from the rain and snow.

To compare this with Susa, we have no evidence to prove the same situation for the Susian glazed bricks, which are also iconographical different from Persepolis.

At Susa, because of some problems like reusing the glazed bricks in later periods, many of them have not been found in their archaeological context. A few remnants of the friezes were found at their original site, but their location is still problematic. Some fragments have a smaller size and due to this we may suggest that they might have been used closer to the ground level or even used at the sides of the walls above the floor.

There are different suggestions about positions of the glazed bricks at Susa. Some of those belong to staircases. The famous sphinxes might have been used in between of two window frames, on pilasters or lunettes above windows or doors (Caubet 1992, 224), or even inside niches (Fig. 4). The Susian guards were found in an area near the entrance of the palace in the West Side of the cour est (Mecquenem 1938, 323-324) and the cour ouest with griffins and winged bulls (Muscarella 1992, 217).

Dating

The exact date for starting major architectural projects at Susa is not clear enough, but it must have started after the second year of

Darius the Great, when he had gained the control of the whole Empire. A fragment of a glazed brick can be a piece belonging to another Bisotun relief that was made for Susa in glazed bricks (Canby 1979, 315-320, Tab. 50). This fragment can be dated to 521-520 BC (Muscarella 1992, 218, No. 2) or even 519 BC because preparing a building until its finishing, designing its decorations and inviting artists needed a longer procedure.

Before completion of the palaces at Susa, Darius decided to start a new project at his ancestral homeland Pars (Ghirshman 1964, 147). Then perhaps the artists, who worked on the Susian workshops for producing glazed bricks, were moved to Persepolis to start a new project. This can be understood from hundreds of fragments of glazed bricks found at Persepolis, which are made exactly in the same style like Susa. The sizes, shapes, methods and techniques are the same, even the architectural signs for positioning the bricks. Unlike the stone sculptors of Susa were not the same people working at Persepolis, because their style and techniques are entirely different.

But for glazed bricks, this is a good evidence for dating parallel bricks. Artaxerxes II informs us that the royal palaces were burned in a fire in the reign of his grandfather Artaxerxes I and he has rebuilt the palaces again (Kent 1953, 154). Therefore the glazed bricks may be recognised as the products of the time of Artaxerxes II and not Darius, because the bricks had been destroyed in the fire (Ghirshman 1964, 140, 142).

At Persepolis we know that the glazed bricks belong to the time of Darius (Muscarella 1992, 218) and Xerxes, there is no evidence for such activity of Artaxerxes II at Persepolis. By comparing different aspects of the glazed bricks we can see how close and parallel they are. It is unlikely that the whole friezes were reproduced after such a long time, exactly as it was before.

It is now widely accepted that the famous glazed bricks of Susa are probably made at the time of Darius the Great and belong to the 6th to early 5th century BC. A number of the glazed brick fragments must have been made at the time of Artaxerxes II. His palace at Shaur had stone reliefs and painted walls (Labrouse & Boucharlat 1972, 83; Boucharlat 1997, pl. 14-15), this shows that he had used other ways for decorating his royal palaces. After the reign of Artaxerxes II we have no evidence for using glazed bricks in Achaemenid buildings. Probably the Achaemenids could make more bricks in the same way, time to time to repair the damaged bricks.

Babylon

In Babylon many Achaemenid glazed bricks were found by R. Koldeway (1914, 104 f.). The exterior walls of a columned palace probably made by Darius at Babylon, was decorated with the glazed bricks and had images of the so-called "Immortal" (Susian) guards (Koldeway 1931, pl. 39; Haerinck 1997, 29). They represent two types of glazed bricks: relief and flat (*Ibid*) and they show

Fig. 4: Frieze showing winged sphinxes and a winged disc, Susa, late 6th century BC, Louvre; Photo: DBM, M. Schicht.

guards, cuneiform inscriptions, floral and geometrical designs (Haerinck 1997, 29-30, also Haerinck 1973, 118f.). Some of the guards are made in life-size and some are made half life-size (Haerinck 1997, 29).

The glazed bricks from Borsippa (Reade 1986, pl. 15a) have parallel designs with Susa and more likely were produced in the Persian Period.

Images and Iconography

Susa has the most varied images of the glazed bricks. They are made in relief and flat bricks. The images at Susa include floral patterns, geometrical designs, human figures and mythological creatures. Few designs look like Babylonian images on glazed bricks, but details are totally different. Also some designs are new images with no iconographical background in Mesopotamian art.

There is a fragment showing heads of roaring lions, repeated on the margin of a brick (Fig. 5). This motive is an Iranian motive and is more related to a northern origin (Muscarella 1992, 230). Parallel examples from Ur in Mesopotamia are dated back to Achaemenid period as well (Kantor 1957, 8-9). They appear in Achaemenid period on textile work, ornaments, seal impressions, coins and

reliefs[4]. The polychrome bricks of the so-called Susian archers (or the Immortals) are another example for repeating motives. They are represented in a row or a repeating procession, now believed toward a central panel with royal inscriptions (Caubet 1992, 224) (Fig. 6). Some fragments with the hands of the "Immortals" join to an inscribed frame (Koldeway 1931, pl. 39a-I). Their dresses are shown in whole details, with patterns, designs and colours. Some designs are floral and some other represents three towers or a fortification on a hill in a square frame. Their skin is painted in dark brown. It is still not clear if they represent Susian guards with a darker skin, or the paint has been changed to brown by some reasons. But there are also other fragments that show faces in pink (Muscarella 1992, 233-234, pl. 161-162).

Perhaps during this time some trainees were also joined to the group of artisans in Susa and moved later with them to Persepolis. But it is hard to suggest why they did not produced human and animal figures at Persepolis. Perhaps in Persepolis it was easier to represent these images in stone reliefs.

In general the glazed bricks have an independent style with some inventions in iconography and style that is typical Achaemenid.

Fig. 5: A glazed tile with lion heads, Susa, late 6th to early 5th century BC, Louvre; Photo: DBM, M. Schicht.

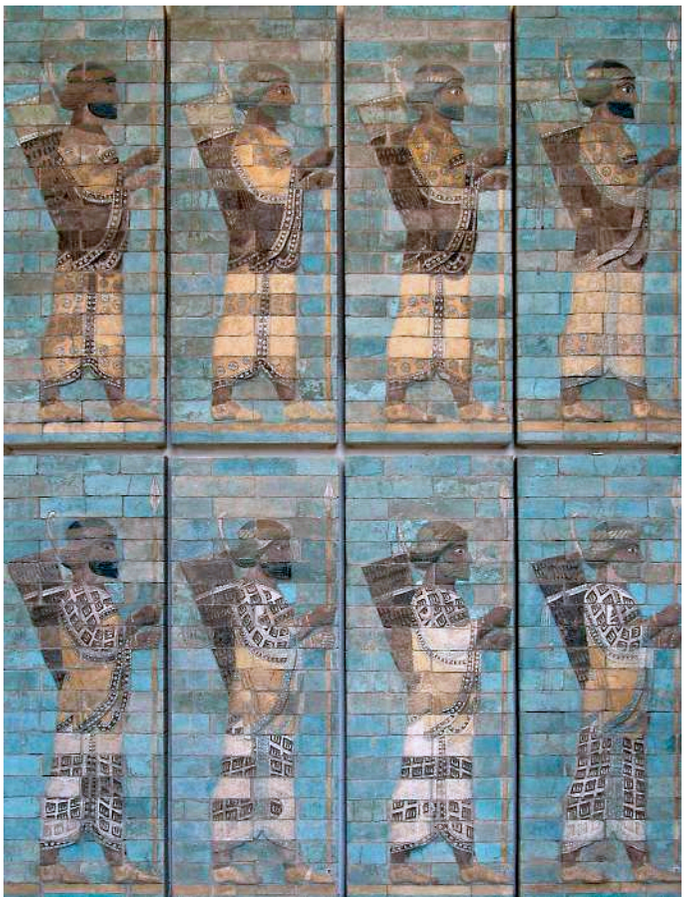


Fig. 6: A frieze of Susian guards, Susa, late 6th century BC, Louvre; Photo: DBM: M. Schicht.

Signs

Achaemenid artisans used signs and markings on each brick in order to organise various fragments correctly and to create a complete panel. These signs are different and they are a kind of architectural sign. In Achaemenid architecture architects adjust each piece correctly with the other used some similar signs (Fig. 7). In Babylon, like Susa and Persepolis such markings are reported by Koldeway for the glazed bricks (Koldeway 1914, 104-105, Fig. 65). The signs in all places include linear signs with a combination of circles and lines. They are drawn on the upper surface of each brick with black ink or glaze or blue and greenish paint.

Colours

Achaemenid glazed bricks have a range of colours both on flat and relief bricksand are protected under the layer of glaze. The colours that can be found on the bricks from Susa and Persepolis are white, yellow, green, brown, blue, greenish blue, lapis-lazuli blue, pink and black. But surprisingly there is no red colour. In Babylon the colours used for the glazed bricks are white, blue, yellow, green, brown and black, but no red colour again (Haerinck 1997, 30). Red colour was widely used for stone reliefs, floors and some columns in the palaces and was made of cinnabar[5]. But it was not common to use it in glazed bricks. According Koldeway there is also a pink colour on the bricks from Babylon that was applied as skin colour that reminds those at Susa (Koldeway 1914, Fig. 64).

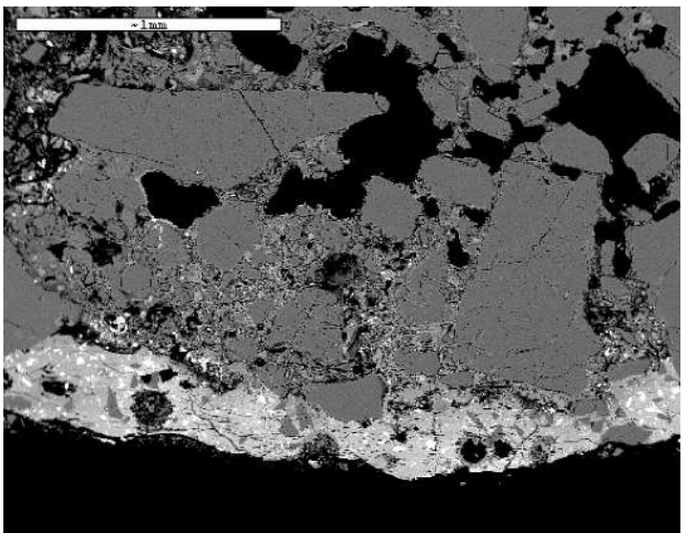


Fig. 8: SEM photomicrograph of glazed Susa brick fragment showing, from bottom to top, glaze layer (light grey) containing a scatter of lead antimonite particles (white) and body consisting of coarse quartz particles (dark grey) bonded together by partially fused feldspar and clay phases (mottled grey).

Report on the scientific examination of a glazed brick from Susa: Glazes[6]

Mike S. Tite & A. J Shortland

Introduction

Four fragments from a single glazed brick from Susa dating to the Achaemenid period were available for scientific examination. These fragments provided two areas of yellow glaze, two of white glaze and one of green glaze.

Fig. 7: An architectural sign on the upper part of a glazed brick from Susa; Photo: National Museum of Iran.

Polished sections through the glaze and body were prepared and were examined in a scanning electron microscope (SEM) with attached energy dispersive spectrometer (EDS) for x-ray analysis. The SEM was operated in backscatter mode so that the different phases present could be identified on the basis of their atomic number contrast, higher atomic number phases appearing brighter in the SEM image. The bulk chemical compositions of the glazes and bodies were estimated from EDS analyses of areas, respectively, some 150x150 μm^2 and 1x1 mm^2 (Fig. 8). For individual phases within the glazes and bodies, the area of analysis was reduced as appropriate. The small areas of unweathered glaze located in the green glaze sample were also analysed using wavelength dispersive spectrometry (WDS) using a 15 μm diameter spot size. In addition to the SEM examination, a small sample was removed from the white glaze for x-ray diffraction analysis (XRD).

Results

The bodies of the Susa bricks consist mainly of coarse, angular particles of quartz, up to about 1 mm across, that are bonded together by partially fused feldspar and clay phases (Fig. 9 & 10). In addition, adjacent to the yellow and green glazes, the bodies contain occasional lead-rich and soda+lead-rich regions respecti-

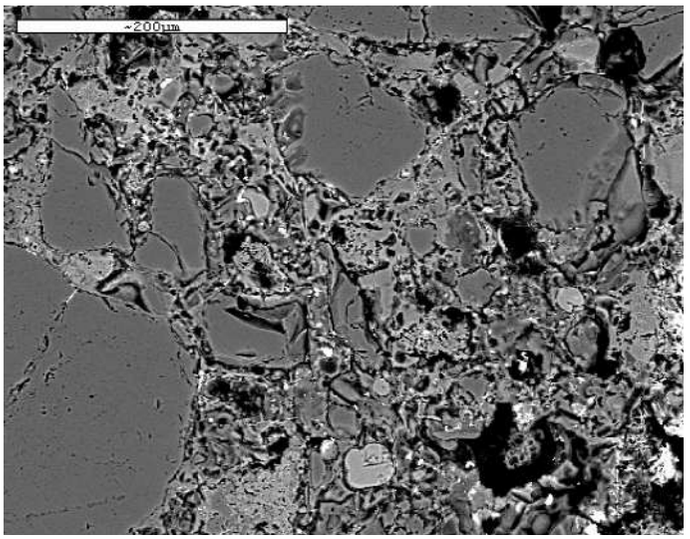


Fig. 9: SEM photomicrograph of glazed Susa brick fragment showing body with partially fused feldspar and clay phases (light grey) bonding together quartz particles (dark grey).

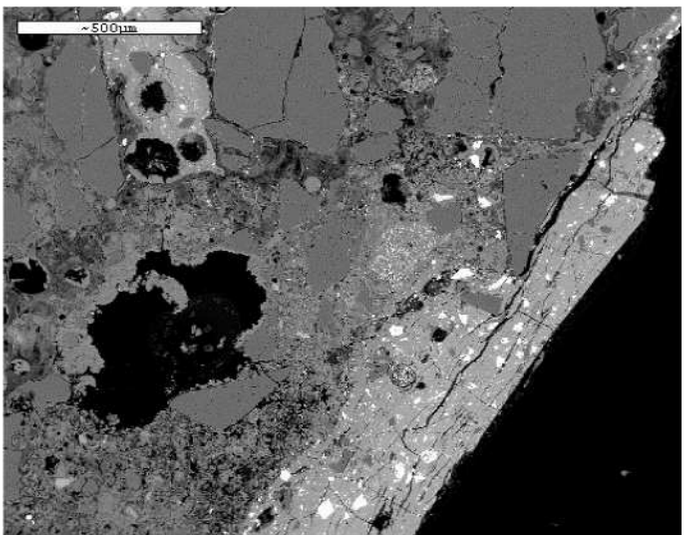


Fig. 10: SEM photomicrograph of glazed Susa brick fragment showing, from right to left, glaze layer (light grey) containing a scatter of lead antimonite particles (white) and body consisting of coarse quartz particles (dark grey) with fragment derived from the applied glazing mixture (light grey with white particles) at top left.

vely which probably represent fragments derived from the applied glazing mixture (Fig. 11).

Both the cracked appearance of the glazes in the SEM and the low alkali contents obtained for their bulk compositions indicate that the Susa glazes are all highly weathered. However, analyses of the small areas of unweathered glaze located in the green glaze sample indicated a soda-rich glaze containing only low concentrations of lime and magnesia, but a high lead oxide content. The green colour of this glaze was achieved through a combination of copper oxide which, by itself, would have produced a turquoise blue glaze and yellow lead antimonite particles which also acted to opacify the glaze. The yellow glaze was similarly opacified by lead antimonite particles (Fig. 9 & 11). XRD analysis indicated that the white glaze was opacified by sodium antimonite ($NaSbO_3$) particles (Fig. 12).

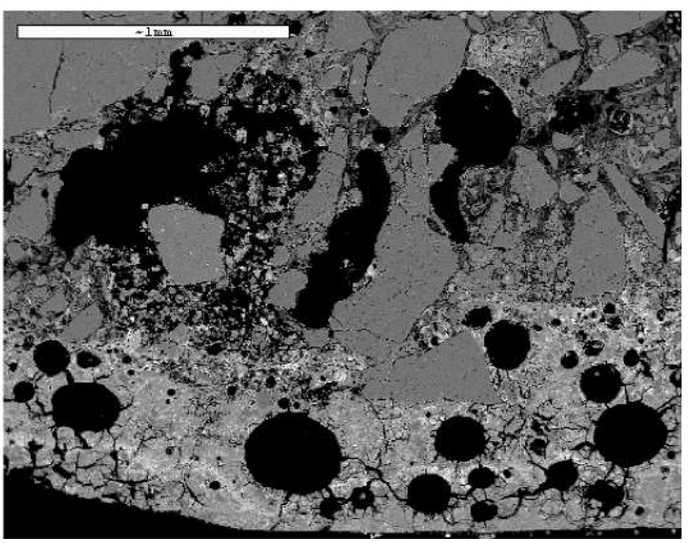


Fig. 11: SEM photomicrograph of glazed Susa brick fragment showing, from bottom to top, glaze layer (light grey) containing a scatter of sodium antimonite particles (white) and body consisting of coarse quartz particles (dark grey) bonded together by partially fused feldspar and clay phases (mottled grey).

Discussion

Caubert & Kaczmarczyk (1998) also found that glazed bricks from the palace of Darius 1st (522-486 BC) at Susa consisted mainly of coarse, angular quartz particles, their bulk compositions, as determined by inductively coupled plasma spectrometry (ICP), being similar to those observed in the present study (Fig. 8). This contrasts with earlier glazed wall plaques from the Neo-Assyrian sites of Nimrud, Ba'shiqa and Arban (Freestone 1991) and glazed bricks from the Ishtar Gate and Processional Way at Babylon (Matson 1986), all of which were produced using calcareous clays, typically containing 15-20% CaO.

Caubert & Kaczmarczyk (1998) do not provide quantitative analyses for their Susa glazes. However, Matson (1986) analysed the glazes from Babylon using an electron microprobe with WDS, and established, on the basis of their high analytical totals, that they were essentially unweathered. These Babylonian glazes are of the soda-lime type and contain significantly higher concentrations of

Iranproben 3359/04-3366/04 Glasuren
REM-EDX, Elementanalyse

measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19				
sample	3359/04 (IR 6/1)			3360/04 (IR 6/2)				3361/04 (IR 6/3)			3362/0 (IR 6/4)			3363/04 (IR-6/5)									R-6/8)
formula	black			yellow				pale green			brown			dark blue									
Na2O	5	5	5	1		1		1	1	1	1	1	1	2	2	1	1		1				
MgO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2							
Al2O3	1	1	1	1	1	1	1	4	4	4	1	2	3	2	1	1	1	1	1				
SiO2	76	79	75	70	70	78	74	56	54	49	78	81	80	69	70	67	6						
P2O5	0																			1		1			1	1
SO2	1	1	1	1							1	1	2	1	2	1							
Cl	1			1							1		1	1									
K2O	3	3	3	2	1	2	2	4	3	3	1	1	1	3	2	3							
CaO	4	4	4	3	3	3	2	3	3	4	12	8	7	6	6	8							
MnO											2	2	2										
FeO	6	6	7	6	9	6	4	3	4	3	1	2	2	10	9	11	1						
CoO														3	2	2	3	1	1	1	1		
CuO	2		2					3	2	2				3	3	3							
Sb2O3					3		4	9	11	14												4	4	3	3
PbO				16	13	8	12	15	17	19													

Fig. 12: Semiquantitative analyses of eight glazes from Susa. 3 to 4 single measurements were taken from one sample. Tin was not detected in any of the samples. All values in wt. %. IR-6/1 etc. are inventory numbers of the Deutsches Bergbau-Museum; 3359/04 etc. are archaeological inventory numbers.

lime and magnesia than those of the unweathered green glaze from Susa (Fig. 8). Thus, the Babylonian glazes fall firmly within the Near Eastern tradition of soda-lime glazes produced from crushed quartz pebbles and soda-rich plant ash derived from saline plants. This type of glaze was first introduced with the beginnings of glass production around 1500 BC (Paynter & Tite 2001) and continued in use through into the Islamic period. The Susa glaze therefore appears to differ slightly from this tradition in using a plant ash with significantly lower lime and magnesia contents, a difference that would have been a factor in increasing its susceptibility to weathering. Further, although glazes opacified with lead antimonite are expected to contain lead oxide in excess of that required to produce lead antimonite, the lead content of the Susa glaze appears to be higher than normally observed, and is certainly significantly higher than that in the yellow Babylonian glazes.

The identification of sodium antimonite as the white opacifier in the Susa glazes was initially unexpected. Without having access to XRD, Caubet & Kaczmarcyzk (1998) had suggested that the white opacifier used in their Susa glazes was calcium antimonite. In addition, using XRD, Fitz (1983) identified calcium antimonite as the white opacifier in the glazes from the Ishtar Gate and Processional Way at Babylon. However, in view of the very low lime content of the Susa glazes (typically less than 2% CaO), the formation of sodium antimonite, rather than calcium antimonite, when antimony oxide is included in the glaze mixture is perhaps not surprising.

Conclusions

The glazed bricks from Susa represent a development from the established technology for glazed brick production in the Near East in a number of different ways. First, a high quartz body has replaced the earlier calcareous clay bodies. Second, the glazes, although within the soda-lime glaze tradition, appear to have used a plant ash with lower lime and magnesia contents, and to have increased the excess of lead oxide over that required for the production of the lead antimonite. Third, probably because of their low lime content, the white glazes were opacified using sodium antimonite rather than the expected calcium antimonite.

Report on the Scientific Examination of a glazed brick from Susa: Colours

Marion Jung & Andreas Hauptmann

Introduction

We received eight additional samples of glazes. These were taken from several bricks from the palace of Darius in Susa, dated to the

beginning of the 5th century BC. They showed eight different colours: black, white, yellow, brown, azure, dark blue, light green and turquoise.

As the samples were very crumbly and fine grained they were not suitable for making thin section for detailed analyses under the scanning electron microscope (SEM) as performed by Tite & Shortland (see above). Hence, we decided to analyse the samples by X-ray diffraction and to present semi quantitative spot analyses made under the SEM by EDS.

Results

According to the results found by Tite & Shortland the X-ray diffraction analyses revealed that all the samples contain quartz (SiO_2) as a main component. Additionally, calcite ($CaCO_3$), gypsum ($CaSO_4 \bullet 2\ H_2O$), and in one case (3366/04; IR-6/8) trona ($Na_3(HCO_3)_2 \bullet 2\ H_2O$) was found. Naturally, any proportions of glass were not detected with this method. Gypsum and trona are considered to have been formed by decomposition of the glaze by weathering processes ("Wetterstein"). As it is known that this, in general, leads to a leaching of alkalis, we may not exclude that also concentrations of K_2O are incorporated in the calcite, in the gypsum and in the trona.

The SEM analyses of the glazes are pretty homogeneous. Note, that no tin was detected in the samples which is well known as an opacifier of glass. It seems not to have been used at Susa in this period.

3359/04 (IR-6/1): black glaze

Main components are SiO_2 (75-80 wt. %), Na_2O (5 wt. %), CaO (4 wt. %), K_2O (3 wt. %) and indicate the glaze to be made up of a soda-potash-lime-glass. In addition, it contains 6-7 wt. % of Fe-oxide, most probably as magnetite (Fe_3O_4) which caused the black colour and masked a blue tint caused by Cu-oxide (2 wt. %). No antimony was detected in this sample. Hence, no sodium antimonite has to be expected as a white opacifier as observed by Tite & Shortland.

3360/04 (IR-6/2): yellow glaze (four analyses)

The glaze is predominantly made up by 8-16 wt. % PbO, 70-78 wt. % SiO_2 and 4-9 wt. % Fe-oxide. This is a typical lead glaze. Such glazes are characterised by low melting points and low viscosities that cause a glossy smooth and well fused surface. As the glaze is yellow we suggest that the colouring agent was lead antimonite ($Pb_2Sb_2O_7$) which also acted as an opacifier.

3361/04 (IR-6/3): turquoise green (three analyses)

Again, the glaze consists of a lead glass with 15-19 wt. % PbO. In contrast to sample 6/2 it is considerably higher in Sb_2O_3 (9-14 wt. %) but, nevertheless, is not of a yellow colour. Probably it is marked by Cu-oxide (2-3 wt. %), and most of the lead antimonite acted to opacify the glass.

3362/04 (IR-6/4): brown (three analyses)

The glassy matrix is made up by SiO_2 (78-81 wt. %) and CaO (7-12 wt. %). MgO is like in the other samples 1 wt. %. It is the only sample that contains Mn-oxide (2 wt. %) which, along with some iron-oxide (1-2 wt. %) detected, is the reason for the brownish stain of the glaze by $(Mn, Fe)_2O_3$.

3363/04 (IR-6/5): dark blue (four analyses)

The glass is a Ca-silicate with 2-3 wt. % potash and 1-2 wt. % sodium while MgO is only slightly higher than in the first four samples. Fe-oxide is around 10 wt.%. Colouring agents are Cu-oxide (3-4 wt. %) and Co-oxide (2-3 wt. %), probably as a Co-spinel ($CoAl_2O_4$).

3364/04 (IR-6/6): turquoise (four analyses)

The composition of the glass is almost identical to sample 6/5. Colouring agents are again Cu- and Co-oxide, but with lower concentrations of Co.

3365/04 (IR-6/7): blue (three analyses)

The glaze consists of a Ca-silicate (SiO_2 76-78 wt. %, CaO 6-8 wt. %) with a little MgO (1-2 wt. %) and K_2O (1 wt. %). The blue colour of the glaze is caused by Cu-oxide which reaches 8 wt. %. No Co was detected in the sample.

3366/04 (IR-6/8): white (four analyses)

The sample contains the highest SiO_2 concentration of all samples (83-85 wt. %), followed by CaO (5-7 wt. %). K_2O is at 1 wt. %, Na_2O partly below 1 wt. %. Sb-oxide is between 3 and 4 wt. %. The white colour most probably was caused by sodium antimonite ($NaSbO_3$) and confirms the observation made by Tite & Shortland (see above) which, according to X-ray diffraction was partly decomposed to Na-carbonate by weathering.

Discussion

The analyses of the glazes from the bricks in Susa performed by the scanning electron microscope do not reflect the original composition. Due to considerable leaching most of the alkalis (Na_2O, K_2O) are removed from the silicate and are replaced by water (hydratisation). "Wetterstein" was formed by corrosion.

According to Wedepohl (2003), most of the glass (and glazes) were manufactured until the late 1st millennium BC by mixing quartz and ashes from plants. Main components of such ashes are calcium carbonate ($CaCO_3$) und potash carbonate (K_2CO_3) if plants from terrestrial vegetation is utilised. If ashes from halophytes are used then sodium carbonate (Na_2CO_3) is a predominating oxide. In any case, $MgCO_3$ is a minor constituent. If heated, carbonates from the ashes are reacting with quartz and are forming silicates while carbon dioxide evaporates. Glasses or glazes made in such a way are high in SiO_2 and contain oxides of Ca, Na, K and Mg. We observe a slightly higher level of K_2O compared to sodium Na_2O, but this does not qualify to decide if the glazes were made from halyphytes or not. What concerns CaO, it is comparable to the analyses by Tite & Shortland. Two of the glazes, a yellow and a green one, were made of lead silicate (3360, 3361).

In the glazes, the following colouring agents were identified: antimony, lead, copper, manganese, iron and cobalt. The yellow colour is caused by Sb-compounds with Ca and Pb, while Na-antimonite leads to a white colour. The light blue and greenish colour is most probably caused by Cu_2+-ions. Perhaps some spots may be coloured by a crystallisation of Egyptian Blue ($CaCuSi_3O_{10}$), but this would need high Cu-concentrations and would opacify the glaze.

The dark blue and light blue coloured samples are of special interest due to their cobalt contents which are based on the addition of special ores. Co-deposits are much rarer than those of copper or even antimony. Also in Iran cobalt ores are rare. Possible sources could be traced at the mines at Qamsar near Kāshān (Th. Stöllner in Pernicka, this volume) or perhaps in Azarbaidjan (Moorey 1994, 191).

Notes

1 For the date see: Potts 1999, 328.

2 For this fragment see: Muscarella 1992, Fig. 164.

3 Ibid: 73-75, pls: XVIII-XIX; Razmjou 2004, forthcoming: Decorative Glazed Pegs with Eye Symbol from Chogha Zanbil. Images from Chogha-Zanbil.

4 Kantor 1957, 8-11, Fig. 6, pl. 6B-C, for coins see: Meshorer & Qedar 1999, 112, No. 156-159.

5 Based on test results from the Smithsonian, a forthcoming paper by the author and Janet Douglas.

6 While preparing the exhibition in Bochum the question arose why not to analyse some of the colours and glazes from the Susa bricks. In collaboration with the National Museum of Iran, Tehrān, and the Deutsches Bergbau-Museum, Bochum, colour and brick samples where collected. While the bricks were analysed in Oxford to provide more information about glazing techniques, the DBM carried out work for a better understanding of the colouring devices.

Bibliography

BOUCHARLAT, R.:
1997 Susa under Achaemenid Rule. In: J. Curtis (ed.), Mesopotamia and Iran in Persian Period, London, 54-67.

BRIANT, P.:
2002 From Cyrus to Alexander: A History of the Persian Empire, Translated by Peter T. Daniels, Eisenbrauns Cameron, G.C.

CANBY, J. V.:
1979 A Note on Some Susa Bricks. Archäologische Mitteilungen aus Iran, NF 12, 315-320.

CAUBET, A.:
1992 Achaemenid Brick Decoration. In: P. Harper, J. Aruz & F. Tallon (eds.), The Royal City of Susa, Metropolitan Museum of Art, New York, 223-225.

CAUBET, A. & KACZMARCZYK, A.:
1998 Les briques glacurees du palais de Darius. Techne 7, 23-26.

CHEVALIER, N.:
1997 Une mission en Perse 1897 - 1912. Les dossiers du musée du Louvre. Exposition-dossier du department des Antiquités orientales 52, Paris.

DIEULAFOY, M. A.:
1893 L'Acropole du Suse d'aprés les fouilles executées en 1884, 1885, 1886, Paris.

FITZ, S. C.:
1983 The coloured glazes of neo-Babylonian wall facings. In: Ceramic Forum International: Berichte der Deutschen Keramischen Gesellschaft 59, 179-185.

FRANKFORT, H.:
1954 The Art and Architecture of the Ancient Orient, Baltimore.

FREESTONE, I. C.:
1991 Technical examination of Neo-Assyrian glazed wall plaques. Iraq 53, 55-58.

GHIRSHMAN, R.:
1964 Persia: From the Origins to the Alexander the Great, translated by Stuart Gilbert and James Emmons.
1966 Tchoga Zanbil (Dur-Untash) 1. Mémoires de la Délegation Archéologique en Iran 39.

GOFF, C.:
1969 Excavations at Baba Jan, 1967: Second Preliminary Report. Iran 7, 115-130.

HAERINCK, E.:
1973 La palais achemenide de Babylone. Iranica Antiqua 10, 108-132
1997 Babylonia under Achaemenid Rule. In: J. Curtis (ed.), Mesopotamia and Iran in Persian Period, London, 26-34.

HEIM, S.:
1992 Plaque With Fantastic Animals. In: P. Harper, J. Aruz & F. Tallon (eds.), The Royal City of Susa, Metropolitan Museum of Art, New York, 206.

KANTOR, H.:
1957 Achaemenid Jewellery in the Oriental Institute. Journal of Near Eastern Studies 16, 1-23.

KENT, R. G.:
1953 Old Persian Grammar, American Oriental Society, New Haven, Connecticut.

KOLDEWAY, R.:
1914 The Excavations at Babylon, translated by A. S. Johns, London.
1931 Die Königsburgen von Babylon. In: Wissenschaftliche Veröffentlichung der Deutschen Orient-Gesellschaft 54, Leipzig.

LABROUSE, A. & BOUCHARLAT, R.:
1972 La fouille du palais du Chaour à Suse en 1970 et 1971. Cahiers de la Délégation Archéologique Française en Iran 2, 61-167.

MALEKZADEH, M.:
2001 Tilework. In: N. Pourjavady & A. Sh. Shahbazi (eds.), The Splendour of Iran, Vol. I, Ancient Times, London, 138-139.

MATSON, F. R.:
1986 Glazed bricks from Babylon – historical setting and microprobe analyses. In: W. D. Kingery (ed.), Technology and Style: Ceramics and Civilisation II. American Ceramic Socie-

ty, Columbus, Ohio, 133-156.
MECQUENEM, R. D.:
1938 The Achaemenid and Later Remains at Susa, In: A. U. Pope (ed.), A Survey of Persian Art 1, Oxford, 321-329.
1947 Contribution a l'étude du palaise achemenide de Suse. Mémoires de la Mission Archéologique de Perse 30, 1-119.
MESHORER, Y. & QEDAR, S.:
1999 Samartian Coinage, Israel Numismatic Society.
MOOREY, P. R. S.:
1994 Ancient Mesopotamian Materials and Industries. The Archaeological Evidence, Oxford.
MUSCARELLA, O. W.:
1992 Achaemenid Art and Architecture at Susa. In: P. Harper, J. Aruz & F. Tallon (eds.), The Royal City of Susa, Metropolitan Museum of Art, New York, 216-218, 227-239.
PARROT, A.:
1961 Nineveh and Babylon, London.
PAYNTER, S. & TITE, M. S.:
2001 The evolution of glazing technologies in the ancient Near East and Egypt. In: A. J. Shortland (ed.), The Social Context of Technological Change, Oxford, 239-254.
PERROT, J.:
1985 Suse à la periode achemenide. Paleorient 11/2, 67-69.

POTTS, D.:
1999 The Archaeology of Elam, Cambridge.
RAZMJOU, SH.:
2003 Iran, die Festung der Urkunden. In: "Der Turmbau zu Babel", Catalogue Graz, Austria, Band IIIa, 205-209 and entries of the catalogue, Band IIIb, Kunsthistorisches Museum, 61-74.
2004 Decorative Glazed Pegs with Eye Symbols from Choga-Zanbil. The National Museum of Iran Publication (forthcoming).
READE, J.:
1986 Rassam's Excavations at Borsippa and Kutha, 1879-82. Iraq 48, 105-116.
ROAF, M.:
2002 Cultural Atlas of Mesopotamia and the Ancient Near East, Andromeda, England.
SCHMIDT, E. F.:
1953 Persepolis I, Oriental Institute of Chicago.
1957 Persepolis II, Oriental Institute of Chicago.
SCHMITT, R.:
2000 The Old Persian Inscriptions of Naqsh-I Rustam and Persepolis. Corpus inscriptionum Iranicarum I.I.II., London.
WEDEPOHL, K. H.:
2003 Glas in Antike und Mittelalter, Stuttgart.