Coptic textiles: dyes, dyeing techniques and dyestuff analysis of two textile fragments of the mak Vienna.

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Introduction
The dating of Coptic textiles requires the combination of art-historical, archaeological and scientific research. Beside textile analysis and radiocarbon (14C) dating, dyestuff analyses can help to date the textiles. The prerequisite is the knowledge about the use of dyes in certain periods which is gained by the study of historic sources as well as by dyestuff analysis, preferably performed on 14C dated textiles.

Two Egyptian papyri, written in Greek in the late 3rd or early 4th century AD, give information on dyeing methods. The Papyrus X Leidensis contains eleven recipes on dyeing wool; in the Papyrus Graecus Holmiensis, seventy instructions on wool dyeing are mentioned, including the use of the dye plants woad and madder, the dye-insect kermes and Tyrian purple. Some recipes deal with the imitation of Tyrian purple by using only the lichen dye orchil or by using woad together with madder. The Greek list of colours P.Oxy LIV 3765, 16–23 from the year 327 AD presents the costly Tyrian purple, a cheaper purple made of madder, a purple obtained perhaps from orchil and kermes in two quality classes.

For the dyestuff analysis of historic textiles microchemical, spectroscopic and chromatographic techniques were developed. Today, dyestuffs mostly are analysed by using high performance liquid chromatography combined with photo diode array detection (HPLC-PDA). During dyeing, each dye leaves a ‘fingerprint’ on the textiles, consisting of a combination of different dyestuffs in various concentrations. Only dyestuffs with a characteristic fingerprint can be identified and only dyestuffs, the use of which is limited to a certain region or a certain period, provide information on the provenance or dating of a textile.

This article gives an overview of the dyes and dyeing techniques used in Late Antiquity in Egypt. In order to obtain more knowledge about the history of two Coptic textile fragments from the Museum für Angewandte Kunst, Vienna (= MAK, Austrian Museum of Applied Arts/Contemporary Art), dyestuff analyses were carried out.

2 Dyes
Vegetable and animal dyes were used for dyeing Coptic textiles. In ancient textiles from Egypt and the nearby Syria and Israel, so far ten dyes have been identified frequently by dyestuff analysis and seven were rarely found. In this paper all important dyes will be described and rarely identified ones will be mentioned.

2.1 Red dyes
The roots of the cultivated plant madder (Rubia tinctorum L.) indigenous to South East Europe and South West Asia have been used as a red dye since Antiquity. The Egyptians most probably adopted mordant dyeing with madder from the region of Palestine during the 18th Dynasty (1550–1292 BC). Textiles dyed with madder contain anthraquinone dyestuffs; alizarin as the main and purpurin as the minor component.

Also the roots of wild madder (Rubia peregrina L.), growing in the Mediterranean region, seem to have been used as a dye. These roots contain the dyestuffs purpurin and some or no alizarin. Analyses on purple hues of Coptic textiles showed only purpurin and indigo. So wild madder was considered to be the dye source. Today, the use of this plant is disputed and the absence of alizarin does not seem to be a criterion for the identification of this plant. The lack of alizarin could be attributed to an unknown dyeing method with madder. Therefore, in recent literature the term ‘madder A’ is used for dyes which contain alizarin as the main dyestuff and ‘madder P’ for those which contain mainly purpurin.

Other important red anthraquinone dyestuffs were supplied by female dye-insects, living on special host plants, such as kermes, Polish cochineal, Armenian cochineal and lac dye. Kermes consists of kermes scale-insects (Kermes vermilio Planchon), which live on kermes oaks (Quercus coccifera L.) native to the Mediterranean region. Textiles dyed with kermes contain kermesic acid as the main dyestuff. The insects of Polish cochineal (Porphyrophora polonica L.) live in Eastern Europe on the roots of Scleranthus perennis L. The Armenian cochineal (Porphyrophora...
**Yellow and brown dyestuffs**

Weld (Reseda luteola L.), originally found in the Mediterranean region and in West Asia, was the main cultivated plant for dyeing yellow. Leaves, stems and petals of the plant contain flavonoid dyestuffs; luteolin as the main and apigenin as the minor component.

Numerous plants, especially galls and barks, supply hydrolysable tannins for dyeing brown, without the use of mordants. With the HPLC method developed for the identification of dyestuffs, the tannin source cannot be identified because only the tannin component ellagic acid is analysed. Seven dyes are rarely identified in textiles found in Egypt or Israel: the four yellow flavonoid-dyes Persian berries (unripe fruits of Rhamnus species), isparak (Delphinium zalil Aitch. et Hemsl.), young fustic (Cotinus coggyria Scop.) and an unknown fustic dye; the two yellow carotenoid-dyes saffron (Crocus sativus L.) and an unknown bixin-dye; and the reddish-brown naphthoquinone-dye henna (Lawsonia inermis L.).

**Blue dyestuffs**

The blue organic pigment indigotin is a vat dyestuff that can be extracted from indigo plants such as woad (Isatis tinctoria L.) and Indigofera species. Woad, naturally distributed from South East Europe to Central Asia, possibly has been cultivated in Egypt since hellenistic time; Indigofera articulata Gouan and Indigofera coerulescens Roxb. occur naturally in the areas of the Arabian desert, the Red Sea and the Nile delta but there are no hints for their cultivation and use in Egypt in the 1st millennium AD. It is assumed that vat dyeing came to Egypt from the region of Palestine in the 18th Dynasty and was used for dyeing linen blue. The use of woad is verified in the Roman epoch, because it is described in the Papyrus Graecus Holmiensis. By chemical analysis of textiles, the source of indigotin cannot be determined.

**Purple dyestuffs**

Tyrian purple (Imperial purple, Royal purple, mollusc purple) was extracted from the hypobranchial glands of three Mediterranean purple snails: the banded dye-murex (Hexaplex trunculus L.); the spiny dye-murex (Balinus brandaris L.) and the red-mouthed rock-shell (Stramonita haemastoma L.). Yarns dyed with Tyrian purple contain the components dibromo-indigotin, monobromo-indigotin, dibromo-indirubin, monobromo-indirubin and indigotin in various concentrations. Tyrian purple was the most expensive dye of Antiquity and textiles dyed with it were status symbols estimated equivalent to or even higher than golden brocade textiles. Most textiles coloured with Tyrian purple originate...
from regions near the habitat of the purple snails like Syria, Phoenicia, Palestine and the later Byzantium, but they are rarely found in Egypt. Textiles found in Egypt and dyed with Tyrian purple are often decorated with golden threads and are dated from the 3rd to the 5th century AD.²⁴

The lichen dye orchil, containing the main colouring matter orcein, was especially gained from Roccella species. It was used as a cheap substitute for Tyrian purple.

3 Dyeing methods
Principally three different sorts of organic colourants (pigments, dyestuffs and tannins) and three different dyeing techniques (mordant, vat and direct dyeing) were used for dyeing textiles in Late Antiquity.

The whole range of colours in Coptic textiles could be produced with the dyes mentioned above by using different dye baths and dyeing methods; by using dye baths in various concentrations; by using various mordants; by dipping textiles in the same dye bath several times and by dipping textiles in different dye baths, so-called combined dyeing.

3.1 Mordant dyeing
In the 1st century AD, Pliny Maior (23/24–79 AD) (NH XXXV, 150) described the art of the Egyptian dyers, who, after pre-treatment with various liquids, succeeded in colouring clothing fabrics in diverse hues in a madder dye bath.²⁵ Most of the water-soluble red dyestuffs (the anthraquinones of madder and insect dyes) and yellow dyestuffs (the flavonoids of weld) have to be fixed on the fibres by mordants. These dyestuffs are called mordant dyestuffs or metal complex dyestuffs.²⁶ After the textiles have been mordanted in a metal-salt solution, they are dyed in a dye bath. Alum, potassium aluminium sulphate, was the most important mordant since Antiquity. It scarcely changes the hue of the dyestuffs, while iron and copper salts produce darker shades. Olive green tones can be attained with cupriforous mordants and weld; purple and violet hues with ferriferous mordants and madder; blacks with ferriferous mordants and tannins.

3.2 Vat dyeing
Blue indigotin and purple dibromo-indigotin are water-insoluble organic pigments, the so-called vat dyestuffs. Textile fibres can only be coloured after the pigments have been reduced and transformed into their water-soluble, yellowish leuco-form, the vat. The textiles are first dipped into the vat and then hung up to oxidise in open air. In this way the leuco-forms are oxidised again into the vat dyestuff forms.

3.3 Direct dyeing
Few dyes contain water-soluble substantive dyestuffs which bind directly to the fibre: yellow saffron, purple orchil, reddish-brown henna and brown tannin-dyes.

3.4 Combined dyeing
Orange, green and purple shades were obtained by using two dyes. Orange hues were gained by mordant dyeing with a yellow and a red dye, for instance weld and madder. To produce green colours vat dyeing with woad or indigo and mordant dyeing with weld were carried out. Purple shades played an important role in Coptic textiles. So-called ‘Egyptian Purple’ was produced by vat dyeing with woad or indigo combined with a mordant dyeing process using madder or kermes. Sometimes textiles were dyed with three or more dyes.

4 The collection of Coptic textiles at the MAK Vienna²⁷
The MAK Austrian Museum of Applied Arts/Contemporary Art Vienna owns a famous collection of Coptic textiles. In 1883 archaeological finds such as tunics, wall hangings, covers, cushions and accessories were for the first time presented to the public in an exhibition in the ‘k.k. Österreichisches Museum für Kunst und Industrie’ (‘Imperial and Royal Museum of Art and Industry’ – today MAK). The exhibition was organised by the art-dealer Theodor Graf who had brought the textiles from Egypt. The catalogue was written by the orientalist Josef von Karabacek. In the same year the museum acquired the core of its collection from Graf, about 700 textiles. Alois Riegl, the museum’s textile curator from 1885 until 1897, laid the solid foundation for a
The textiles of an early Christian burial from el-Kom el-Ahmar/Šaruna (Middle Egypt) TEXTILES DATED BY THE ARCHAEOLOGICAL CONTEXT

The tradition of scholarly research when he made the Coptic textiles subject of its investigations and published a catalogue in 1889. Today the collection consists of about 1200 objects. In the years 2005 and 2006 the MAK’s textile curator’s research has been summarised in an exhibition and a catalogue that includes textile technological studies. The whole collection is accessible for the public on the internet since the end of 2006.28

4.1 The investigation of the two Coptic textiles of the MAK Vienna

The first textile concerns a fragment of an Egyptian garment ornamented with multicoloured clavi and neckbands and the second one is a purple medallion with golden and white ornaments.

The aim of the dyestuff analysis of the clavi and the neckbands was to identify the dyes, to find out the correlation between the dyes and the colours, to look for differences between the clavi and the neckbands and to identify a dye which can be useful for dating the object. The purple yarn and the metal thread of the purple medallion were analysed in order to verify former results.

The dyestuffs of both textiles were analysed by HPLC-PDA according to the method by Jan Wouters and Noemi Rosario-Chirinos with some minor modifications.29 Additionally, scanning electron microscopy with energy-dispersive X-ray analysis (SEM-EDX) was used for the examination of the metal thread.

2.2 Dyestuff analysis of the fragment of a linen tunic with clavi and neckbands

MAK inv. no T 8528-1928

In 1928 this fragment of an Egyptian tunic came to the museum from the private collection of Johanna Nadherny-Borotin. It measures 128 x 35 centimetres. The linen ground fabric consists of an S-spun warp and an S-spun weft. Two different tapestry woven textiles, about 8 cm wide, are attached to the linen ground: the vertical units of the clavi and the transverse neck decoration, the neckbands (figs 1–3).

Both tapestries are made of a linen warp, S-spun and Z-plied. The weft is made of dyed wool, S-spun, and of wool and linen of natural colour, S-spun.30 Eight woollen yarns of different hues were used for the clavi and four woollen yarns of different tones for the neckbands. The colours of the neckbands are deeper than those of the clavi, which seem to have faded. The ornaments of the neckbands

28 See link ‘Late Antique Textiles’ at: http://sammlungen.mak.at.
30 CAT. VIENNA 2005, 92–93, NO 41; KNALLER/STÜHRENSBERG 2006, 12.
The textiles of an early Christian burial from el-Kom el Ahmar/Šaruna (Middle Egypt)

Textiles dated by the Archaeological context
consist of small medallions and birds. Seven different scenes are present on the clavi (figs 4–10). In a recently carried out iconographical study of this tunic some of the scenes are described as Old Testament themes and the textile was identified as a Christian garment, though its decorative elements seem to be influenced by Jewish and Islamic ideas.\textsuperscript{31} The interpretation of the almost completely preserved clavi allows to place the Egyptian tunic in the Late Antique or Early Islamic period, most probably in the 7th or 8th century AD.\textsuperscript{32}

\textsuperscript{31} Pillinger 2002, 18–31.

\textit{fig 4} Detail of the clavi, a male and a female figure (Adam and Eve).
\textcopyright maf Vienna. Photo by E. Hütter, ika.
fig 5  Detail of the clavi, a shepherd. © MAK Vienna. Photo by E. Hütter, I.K.A.
fig 6  Detail of the clavi, a female figure with child. © MAK Vienna. Photo by E. Hütter, IKA.
fig 7  Detail of the clavi, a male figure and an animal with a long neck.
© MAK Vienna. Photo by E. Hütter, ika.
fig 8  Detail of the clavi, a male figure (‘camel driver’) with an animal bearing a saddle. © MAK Vienna. Photo by E. Hütter, IKA.
fig 9  Detail of the clavi, a female figure on a four-wheeled wagon.
© MAK Vienna. Photo by E. Hütter, IKA.
fig 10  Detail of the clavi, a female figure (‘rider’) with two animals.
© MAK Vienna. Photo by E. Hütter, ika.
4.2.1 Results and discussion

Thirteen dyestuffs analysed in the yarns of the clavi and the neckbands could be associated with four dyes. The correlation between the colours of the yarns, the analysed dyestuffs and the identified dyes is shown in tables 1 and 2.

The clavi have a red ground dyed with madder. Weld was used for the yellow of the border stripes. To create the blue shades, various concentrations of indigotin were used, most likely extracted from woad. Also mixtures of two dyes were identified. The turquoise (bluish-green) fibres of the border stripes were dyed with indigotin and weld, the orange (salmon) hues in objects of the scenes with madder and weld.

In the samples of the neckbands one, two and three dyes were found. To obtain the black-blue colour only vat dyeing with indigotin was used, but the dark-blue was additionally shaded with weld. The orange tone of the birds was produced with madder and weld. The green hue was made with indigotin, weld and madder and the bluish-red of the small medallion with lac dye, madder and woad (or indigo).

Similar mixtures of two and three dyes were also identified in other Coptic textiles. The combination of madder and weld was found in one yellow and five orange samples of Coptic textiles from Flemish private collections, furthermore in one orange and in two yellow samples from Coptic textiles of the Abegg-Stiftung. The result of the green hue in the neckbands, including the amount of weld and madder relative to the amount of indigotin, corresponds with the analysis of the green yarn from a Coptic textile in a Flemish private collection. The combination of lac dye, madder and an indigotin-plant was for the first time identified in the bluish-red colour of the neckbands. In a blue-violet sample from a textile of the Abegg-Stiftung the same mixture was found, but additionally brazilwood and tannins.

The clavi and the neckbands differ not only in motives and colours, but also in the identified dyestuffs and dyes. The colours are more striking in the neckbands than in the clavi. Some differences concerning the dyes could be found by analysis of the clavi and the neckbands: while mixtures of two dyes were analysed in both tapestry ornaments, mixtures of three dyes were only found in the neckbands. Lac dye was only identified in the neckbands. In all the weld-dyed yarns of the neckbands the dyestuffs luteolin and apigenin occur. In the fibres of the clavi only luteolin or luteolin and an apigenin equivalent were analysed. The lack of apigenin in the samples of the clavi is correlated to a low concentration of luteolin. Both results may be due to fading of the colours in the clavi or may indicate that small amounts of weld were used for dyeing. When the tunic was made, the neckbands and the clavi were attached to the linen ground fabric at the same time. It can be excluded that the neckbands were fixed on the tunic at a later period. So the differences may be due to different dyeing techniques leading to a different sensitivity to fading. It may also be true that fading processes took place during the previous use of the clavi elsewhere.

### Table 1 Dyestuffs and dyes of the clavi.

<table>
<thead>
<tr>
<th>Colours of the samples</th>
<th>Analysed dyestuffs</th>
<th>Identified dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>yellow</td>
<td>luteolin</td>
<td>weld</td>
</tr>
<tr>
<td>red</td>
<td>alizarin, purpurin</td>
<td>madder</td>
</tr>
<tr>
<td>light blue, blue, dark blue</td>
<td>indigotin, indirubin</td>
<td>woad (or indigo)</td>
</tr>
<tr>
<td>turquoise (bluish-green)</td>
<td>indigotin, luteolin</td>
<td>woad (or indigo)</td>
</tr>
<tr>
<td>orange (salmon)</td>
<td>alizarin, purpurin, alizarin equivalent luteolin</td>
<td>weld</td>
</tr>
</tbody>
</table>

### Table 2 Dyestuffs and dyes of the neckbands.

<table>
<thead>
<tr>
<th>Colours of the samples</th>
<th>Analysed dyestuffs</th>
<th>Identified dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>black-blue</td>
<td>indigotin, luteolin</td>
<td>woad (or indigo)</td>
</tr>
<tr>
<td>dark blue</td>
<td>indigotin, luteolin</td>
<td>weld</td>
</tr>
<tr>
<td>orange</td>
<td>alizarin, purpurin</td>
<td>madder</td>
</tr>
</tbody>
</table>

33 Hofmann-de Krijzer/Van Bommel (in press).
34 Wouters 1993, 61–62, code nos 34/1, 34/2, 70/1, 133/2, 135/2, 138/1. The numbers before the slash correspond to the catalogue numbers in Cat. Zottegem 1993, 125–126, cat. 34; 166–168, cat. 70; 243–244, cat. 133; 246, cat. 135; 249, cat. 138.
35 Schrenk 2004, 479–481 (table 2, nos 7, 8, 53), and 47–53, nos 7–8; 53–62, no 53.
36 Wouters 1993, 61, code no 34/6; Cat. Zottegem 1993, 125–126, cat. 34.
37 Schrenk 2004, 481 (table 2, no 114), and 273–275, no 114.
4.2.2 Dating

Lac dye is among the six dyes which can give a meaningful dating in the 1st millennium AD.\textsuperscript{38} Forbes mentions that in Egypt lac dye appears when the connections with Armenia, Byzantium and the North were interrupted by the Arab invasions of the 7th century AD. Hence Armenian cochineal and kermes were unobtainable. Lac dye may have been known in earlier time but it was hardly used.\textsuperscript{39} The detection of lac dye in several textiles from Egypt confirms Forbes’ statement. The dye was detected in a Coptic textile of a Flemish private collection which, according to \textsuperscript{14}C-dating, should be dated between the second half of the 8th and the end of the 10th century AD.\textsuperscript{40} In four textiles of the Abegg-Stiftung lac dye was identified. Two of them were dated from the 7th to the 9th century AD by \textsuperscript{14}C-dating\textsuperscript{41} and the other two were dated from the 6th to the 9th century AD by iconographical studies.\textsuperscript{42}

The plied linen warp of the clavi and the neckbands gives an additional hint to the dating of the tunic. Coptic tapestry ornaments on plied linen warp are probably mostly later than those in which the linen warp is not plied. Most of the pieces with plied linen warp are not \textsuperscript{14}C-dated but seem to be later than the late 6th century AD; only few textiles with applied decoration having a plied warp are known which are dated earlier.\textsuperscript{43}

It can be concluded that the results of the scientific research support the dating of the tunic to the 7th or 8th century AD according to art-historical research.

4.3 Dyestuff analysis of an orbiculus, purple tapestry with geometrical patterns

\textbf{MAK inv. no T 10069-1953}

In 1905 two textile fragments fixed on the front and the back of the same linen support fabric came to the museum, originating from Theodor Graf’s inheritance. Both of them are medallions. In the year 1953 the orbiculus MAK inv. no T 10069-1953 has been stitched to another linen support fabric while the other medallion stayed on the primary support fabric and kept the MAK inv. no T 6025-1905.

This tapestry woven medallion measures 13 x 16 cm. The size of the orbiculus indicates its use on a tunic.\textsuperscript{44} On a purple ground there are small four-leaved ornaments made of golden metal threads and white geometrical lines (fig 11). The warp is made of wool of a natural colour, S-spun, and the weft is made of purple wool, Z-spun and S-plied. Linen yarns of natural colour, S-spun, were used for the geometrical white lines. The metal thread, Z-spun, has a silk core, Z-spun. The medallion is believed to date between the 2nd and the 4th centuries AD.\textsuperscript{45}

In the 1930s Rodolphe Pfister chose this textile for dyestuff analysis. Since 1934 this French chemist and pioneer in the field of dyestuff analysis of antique textiles analysed many purple textiles from Egypt, but Tyrian purple he could find in two objects only. This medallion is one of them. In ‘Nouveaux textiles de Palmyre’ he describes the analysis of the purple wool sample:\textsuperscript{46} ‘… l’acide chlorhydric-

<table>
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<th>Colours of the samples</th>
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<th>Identified dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>black-blue</td>
<td>indigotin, indirubin</td>
<td>woad (or indigo)</td>
</tr>
<tr>
<td>dark blue</td>
<td>indigotin, indirubin, luteolin, apigenin</td>
<td>woad (or indigo)</td>
</tr>
<tr>
<td>orange</td>
<td>alizarin, purpurin, alizarin equivalent</td>
<td>madder</td>
</tr>
<tr>
<td>green</td>
<td>indigotin, indirubin, luteolin, apigenin</td>
<td>weld</td>
</tr>
<tr>
<td>bluish-red</td>
<td>five laccaic acids, alizarin, purpurin</td>
<td>lac dye</td>
</tr>
</tbody>
</table>

\textsuperscript{38} Verhecken, in the present volume, p. ***.
\textsuperscript{39} Forbes 1964, 107.
\textsuperscript{40} Wouters 1993, 60, code no 145/1; Cat. Zottegem 1993, 237–259, cat. 145.
\textsuperscript{41} Schrenk 2004, 479–481 (table 2, nos 114, 146), and 273–275, no 114; 319–321, no 146.
\textsuperscript{42} Schrenk 2004, 479–481 (table 2, nos 115, 159), and 275–277, no 115; 343–344, no 159.
\textsuperscript{43} De Jonghe/Verhecken-Lammens 1993, 38; private communication to Chris Verhecken-Lammens on 03.06.2006.
\textsuperscript{44} Cat. Vienna 2005, 164, no 98.
\textsuperscript{45} Cat. Vienna 2005, 164, no 98; Knaller/Stührenberg 2006, 23.
\textsuperscript{46} Pfister 1937, 12.
Identification of Tyrian purple in the metal thread of the orbiculus by HPLC-PDA.

Identification of pure gold in the metal thread of the orbiculus by SEM-EDX.

Identification of Tyrian purple in the purple thread of the orbiculus by SEM-EDX.

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Identification of Tyrian purple in the purple thread of the orbiculus by SEM-EDX.

Identification of Tyrian purple in the purple thread of the orbiculus by SEM-EDX.

The textiles of an early christian burial from el-Kom al Ahmar/Saruna (Middle Egypt).

result from the 1930s that this textile was dyed with Tyrian purple. The result of the SEM-EDX analysis of a metal thread was that it consists of pure gold (fig 13).48

Tyrian purple has been detected only in six other textiles found in Egypt: in ‘un petit carré de style hellénistique’ from the coll. R. P.,49 in a tapestry woven medallion, worked in purple wool dated to about the 5th century AD,50 in a woolen ornament of an Egyptian mantle in the British Museum, London, dated to the 3rd century AD,51 in a Coptic textile from a Flemish private collection,52 and in two purple medallions from the Abegg-Stiftung.53

4.3.2 Dating

The dating of the purple medallion between the 2nd and the 4th centuries AD was not based on scientific research until now.54 In any case it can be placed in the time between the 3rd and the 5th centuries AD, because all textiles found in Egypt, dyed with Tyrian purple and decorated with golden threads are dated to this period.55 Textile fragments which resemble the Viennese orbiculus are known from the Abegg-Stiftung. The woolen threads are dyed with Tyrian purple and the metal threads are likewise made of pure gold. According to 14C-analysis these medallions are dated between the early 2nd and the middle of the 4th century AD.56

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