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ARCHAEOMETRIC CHARACTERIZATION OF A GROUP OF GOLD JEWELRY FROM THE DIYARBAKIR ARCHAEOLOGICAL MUSEUM

DİYARBAKIR ARKEOLOJİ MÜZESINDEKİ BIR GRUP ALTIN TAKININ ARKEOMETRİK KAREKTERİZASYONU

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ABSTRACT

Jewelry is a material relic that people have used for various purposes and assigned various meanings to from the past to the present. Jewelry allows us to identify people's beliefs, cultures, social relationships, and even the technologies they used during the time they were made. With the discovery of mines and the advancement of technology, jewelry made from ready-made materials found in nature in the early periods has been replaced by precious metals, stones, and alternative materials. Gold jewelry and jewelry pieces acquired through purchase and confiscation have been examined at the Diyarbakir Archaeological Museum to observe this change. The artifacts cannot be dated because they have not been discovered through systematic excavations and the context in which they had been discovered is unidentified. Furthermore, because there is no method for archaeometrically dating gold artifacts, national and international jewelry catalogues, articles, and theses written on jewelry have been studied in the dating of jewelry covered by the study. Following these reviews, visual comparisons have been used to determine the possible dates of the jewelry. The chemical composition of the gold jewelry and jewelry pieces has been determined using the Portable Energy Dispersive X-ray Fluorescence spectrometer (P-EDXRF) after visual descriptions of the gold jewelry and jewelry pieces have been made. It has been attempted here to comprehend how the gold ratio in jewelry changes on periodically basis in this study, 17 gold artifacts have been introduced, and the analysis results have been interpreted. When the overall chemical composition of the artifacts has been examined, gold + silver and gold + silver + copper content has been determined as a result of the analysis. The gold content in pre-Roman jewelry has been lower than in Roman jewelry, and the majority of the artifacts have been electrum, according to periodic comparisons of the contents of these alloys. It was acknowledged that

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in ancient gold production technology that artifacts have been produced by using the element of gold and alloys in which the ratio of gold was reduced together with silver. This tradition is found to be coincided with the artifacts after 2800 BC, when gold production began, and the Lydian Period (7th century BC and later), when the separation of gold and silver has been discovered.

Keywords: Archaeometry, Diyarbakır Museum, Copper, Gold, Jewelry, Metal, P-EDXRF, Silver.

ÖZET

Takılar, geçmişten günümüze insanların farklı amaçlar doğrultusunda kullandıkları ve farklı anlamlar yükledikleri maddi kalıntılardır. Takılar yapıldıkları dönemlerdeki insanların inançlarını, kültürlerini, sosyal ilişkilerini ve hatta kullanmış oldukları teknolojilerin tanımlanabilmesini sağlamaktadır. Erken dönemlerde doğadaki hazır malzemeleri kullanarak yapılan takılar madenlerin keşfi ve teknolojinin ilerlemesi ile yerini değerli madenlere, taşlara ve alternatif malzemelere bırakmıştır. Bu değişimi görebilmek amacı ile Diyarbakır Arkeoloji Müzesi'ne satın alma ve müsadere yolu ile kazandırılmış olan altın takı ve takı parçaları incelenmiştir. Eserler sistemli kazılar sonucu bulunmadığı ve bulundukları konteksin belli olmaması nedeniyle tarihlendirilememiştir. Bunların yanı sıra arkeometrik olarak da altın eserlerin tarihlendirilmesine dair bir yöntem bulunmaması nedeniyle çalışma kapsamındaki takıların tarihlendirilmesinde ulusal ve uluslararası takı katalogları, takılar üzerine yazılmış makale ve tezler incelenmiştir. Bu incelemeler sonrası takıların olası tarihlerinin belirlenmesi görsel karşılaştırmalar sonrası yapılmıştır. Altın takı ve takı parçalarının görsel tanımlamaları yapıldıktan sonra P-EDXRF (portatif Enerji Dağılımlı X-Işınları Floresans) Spektrometresi ile kimyasal kompozisyonları tespit edilmiştir. Böylelikle takılar içerisindeki altın oranının dönemsel olarak nasıl değişim gösterdiği anlaşılmaya çalışılmıştır. Bu çalışmada 17 adet altın eser tanıtılıp analiz sonuçları yorumlanmıştır. Analizler sonucu genel kimyasal kompozisyona bakıldığında eserlerde altın+gümüş ve altın+gümüş+bakır içeriği tespit edilmiştir. Bu alaşımların içerikleri dönemsel olarak da karşılaştırılınca Roma Dönemi öncesi takılarda altın içeriğinin Roma Dönemi takılarına oranla daha düşük olduğu ve eserlerin çoğunluğunun elektrum olduğu tespit edilmiştir. Antik dönem altın üretim teknolojisinin altın elementi ve altın oranın düşürüldüğü alaşımlarda ise gümüş ile birlikte kullanılarak eser üretildiği anlaşılmıştır. Bu geleneğin altın üretiminin başladığı M.Ö. 2800'den ve altın ve gümüşün ayrıştırılmasının öğrenildiği Lidya Dönemi M.Ö. 7.yy ve sonrası eserlerle genel olarak örtüştüğü anlaşılmıştır.

Anahtar Kelimeler: Altın (Au), Arkeometri, Bakır (Cu), Diyarbakır Müzesi, Gümüş (Ag), Metal, P-EDXRF, Takı.

INTRODUCTION

In recent years, it has taken an important role in promoting collaboration between science and art, particularly cultural heritage, through advanced non-destructive analysis methods. The use of Science and Natural Sciences, as well as material remains in the archaeological finds class, has become mandatory in order to fully determine all aspects of civilization's history. As a result of these factors, the "Science of Archaeometry" has emerged (Birgül 1981). Archaeometric studies have begun in Turkey with the field applications within the scope of the Keban Project, which has been started by Middle East Technical University in 1968 (Özdoğan 2012). Jewelry that is classified as archaeological artifacts and consists of material ruins that humanity has used for various purposes and functions from the past to the present. Jewelry has a history that is almost as old as human history. Initially, jewelry has been made from raw materials found in nature, however with the discovery of mines and the advancement of technology, these natural raw materials have been replaced by mines, precious stones, and alternative materials (Zaimoğlu and Kaplanoğlu 2012). The materials used in jewelry production are closely related to the purpose of the jewelry, the technological sophistication, and the economy of the period and society in which it was made. People continued to make jewelry even when the economy had been bad. Instead of using expensive and difficult-to-obtain materials, they continued to make jewelry out of glass, iron, and bronze, even experimenting with coating methods and attempting to imitate precious metals by coating worthless mines with mechanical and then chemical methods (Köroğlu 2004). Faunal ruins discovered in Hatay-Üçağızlı Cave, dating to the early Upper Paleolithic Age, indicated that crustaceans collected from beaches were used for both nutrition and ornamentation. These ornamental marine crustaceans were pierced and turned into beads, which had been then used as jewelry (Güleç et al. 2013). During archaeological excavations at the Neolithic Age Without Pottery Konya - Boncuklu Mound, beads and necklaces from sea snails have been discovered on or around some of the human skeletons found in a number of open-air graves (Baird 2016). Furthermore, the presence of a large number of copper and lead beads is mentioned in Çatalhöyük, which dates back to the Neolithic Age (Yalçın 2003). As the Bronze Age approaches, copper ornaments, which have been popular from the Neolithic to the Chalcolithic Ages, are being phased out in favor of arsenic copper, bronze, gold and silver (Başak 2005). With the beginning of the Bronze Age in Anatolia, the people here have been able to obtain bronze by combining tin with copper, and bronze rapidly entered daily life. Bronze with copper, gold, and silver, such as precious and semi-precious metals, forging, casting techniques using different metals and manufactured to work the mines, and many learning techniques of jewelry with a variation in the art and craftsmanship have been observed over time (Bingöl 1999). Some of the most beautiful examples of the period are discovered in the Alacahöyük King Tombs dated to the first Bronze Age and in jewelry recovered during the Troy excavations. Jewelry dating to this period was usually bracelets, ornate pins, hairpins, and chains made of gold electrum and silver (Köroğlu 2004). Gold has been one of the oldest metals used by humans for different purposes. Due to its scarcity in nature, natural luster, and easy processing, it has been more valuable than other metals. Gold ornaments were found in archaeological layers of the 5th and 4th thousand BC (Oygür 1990). Gold is not a pure mine, it is found in riverbeds, in small crumbs among alluvial deposits, and also in lodes in quartz-based rocks (Erginsoy 1978). Some of Anatolia's first gold artifacts, dating from the first half of the third millennium BC, have been discovered in Troy, Alacahöyük, Eskiyapar, and Horoztepe. These metals, which contain 2-30% silver, are not pure gold, but are known as "Electrum." Previously, these metals were used in the production of jewelry and status-determining works (Özbal 2013). The first finds related to gold purification, made with the desire to obtain pure gold, have been discovered during excavations at Sardes, Lydia's capital (Ramage 1970). Following this period, pure gold and more conscientious alloys are found in gold jewelry artifacts. Prior to this period, an average of 20% of the silver found in gold came from a natural electrum alloy, not an artificial alloy. Purification technology produced pure gold and electrum artifacts after the Lydian period.

Archaeometric studies on jewelry can present data on jewelry production technologies, determination of raw materials used, changes of these raw materials according to the purpose of use and the period of construction. In this context, visual descriptions of gold jewelry and jewelry pieces purchased and confiscated by the Diyarbakir Archaeological Museum have been made and alloy ratios have been determined using the P-EDXRF spectrometer. The works have been visually described, and then analyses have been performed with the P-EDXRF spectrometer at various points for each work, and their contents have been determined by averaging these analyses. Because it is illegal and unethical to take samples from inventory artifacts for destructive analysis, the P-EDXRF method, which is non-destructive and less reliable than destructive methods, has been chosen. The results of the analysis obtained have been compared primarily in groups formed among themselves, and then similar studies and periodically identical works have been compared with the results of analysis of gold artifacts obtained after the excavations of the Temple of Artemis of Ephesus and gold jewelry of the Museum of Italy/Taranto. In addition, the gold artifacts recovered from archaeological excavations conducted by Archaeologist/Archaeometrist Assoc. Prof. Dr. Mahmut AYDIN in different regions of Anatolia have been compared with the results of the analysis of 353 gold jewelry created by P-EDXRF analysis.

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Table 1: Bronze CRM certificate value and its P-EDXRF analysis results. / *Tunç SRM sertifika değeri ve onun P-EDXRF analiz sonuçları.*

	Ag	Sb	As	Cu	Fe	Ni	Pb	Si	Sn	Zn
SRM	0.002	0.006	0.003	90.08	0.007	0.004	1.99	0.002	0.029	7.81
P-EDXRF	ND	ND	ND	90.11	ND	0.019	1.7	0.1	ND	7.89

MATERIAL AND METHOD

The visual descriptions and dating of 17 pieces of gold jewelry and jewelry pieces, which were acquired by the purchase and confiscation of the Diyarbakir Archaeological Museum, have been carried out after the statements in the inventory records and the National/International catalog, National/International articles and national thesis scans. The working group includes two rings (Plates 1.11-12), 13 earrings (Plates 1.1-10/13-15), one jewelry piece (Plates 1.16) and one bracelet (Plate 1.17a-b). Different archaeometric methods can be used to determine the chemical composition of metal artifacts.[1] The chemical composition of metal artifacts can be determined using a variety of archaeometric methods. Energy-dispersive X-ray fluorescence spectroscopy (P-EDXRF) was one of these methods used to determine the chemical composition of the works covered by this study. This method has been used because the removal of artifacts from the museum, as well as the removal of parts, is not permitted. The purpose of selecting the P-EDXRF method is that the method is non-destructive, as well as providing in situ analysis, providing immediate access to results, and analyzing many different points of a single work (Potts and West 2008). Innov-X-Olympus Omega Portable Energy Dispersive X-ray Fluorescence Spectrometer (P-EDXRF) has been used in the study, and 26 elements (Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Au, Ge, Os, Ir, Pt, Pb, Bi, Zr, Mo, Ru, Rh, Pd, Ag, Cd, Sn, Sb, Le) can be analyzed at the same time. First and foremost, the spectrometer has been tested using certified reference material to determine the accuracy deviation in spectrometer analysis results. Bronze (CAD 314 UNS C31400) (Table 1, Figure 1) and silver (132x925Zn3) (Table 2, Figure 2) Certified Reference Materials (CRM) has been used for the reliability of the spectrometer.

As can be seen from the analysis results, the P-EDXRF analysis results and the laboratory measurement results of silver and bronze SRMs are coherent, demonstrating the dependability of the spectrometer used in metal analysis.

Figure 1: Certified bronze reference materials sample used for P-EDXRF spectrometer reliability (CDA 314UNS C31400). / *Spektrometrenin güvenirliliği için kullanılan sertifikalı tunç referans (CDA 314UNS C31400).*

Table 2: Silver CRM certificate value and its P-EDXRF analysis results. / *Gümüş SRM sertifika değeri ve onun P-EDXRF analiz sonuçları.*

	Ag	Cu	Zn
SRM	92.64	4.53	2.88
P-EDXRF	91.95	5.19	2.85

Figure 2: Certified silver reference material used for spectrometer reliability (132x925Zn3). / *Spektrometrenin güvenirliliği için kullanılan sertifikalı gümüş referans (132x925Zn3).*

ANALYSIS RESULTS AND DISCUSSION

A P-EDXRF spectrometer has been used to analyze 17 pieces of gold jewelry and jewelry as part of the study. Gold (Au), silver (Ag), and copper (Cu) have been discovered in the general chemical composition of the artifacts. Iron (Fe), chromium (Cr), cadmium (Cd), and titanium (Ti), in addition to these elements, have been discovered as trace elements. All works had a gold average of 79.5%, a silver average of 17.4% and a copper average of 2.8% (Table 3; Figure 3-4).

1 The photos of the artifacts are arranged in the order shown in Table 3.

Table 3: P-EDXRF analysis results of the artifacts (%) (*: Period included in museum inventory records, **: The period has not been determined in the museum inventory records, but the period determined by the researchers after the catalog scans for the thesis material.). / *Eserlerin P-EDXRF analiz sonuçları (%) (*: Müze envanter kayıtlarında yer alan dönem, **: Müze envanter kayıtlarında dönemleri belirlenmemiş ama tez malzemesi için yapılan katalog taramaları sonrası, araştırmacılar tarafından tespit edilen dönem).*

Inventory Number	Explanation	Period	Au	Ag	Cu	Fe	Cr	Cd	Ti
8/12/82	Earring	8th -7th century BC**	52.2	43.4	4.4	ND	ND	ND	ND
21/7/84	Earring	8th -7th century BC**	60.1	37.0	1.5	1.2	ND	ND	ND
21/5/84	Earring	7th century BC **	88.6	7.4	3.8	ND	ND	ND	ND
15/35/75	Earring	7th century BC **	97.2	2.7	ND	ND	ND	ND	ND
21/4/84	Earring	7th century BC **	75.4	21.6	2.9	ND	ND	ND	ND
21/6/84	Earring	7th century BC **	75.8	21.6	2.4	ND	ND	ND	ND
8/14/82	Earring	7th century BC **	76.0	20.0	3.0	ND	ND	ND	ND
21/3/84	Earring	7th century BC **	78.5	18.9	2.4	ND	ND	ND	ND
21/2/84	Earring	7th century BC **	75.5	17.8	2.8	1.2	2.4	ND	ND
8/13/82	Earring	7th century BC **	83.4	12.6	3.8	ND	ND	ND	ND
10/11/97	Ring	Rome *	92.1	7.8	ND	ND	ND	ND	ND
23/1/09	Ring	Rome *	99.5	0.5	ND	ND	ND	ND	ND
5/2/03	Earring	Rome *	91.4	6.9	1.4	ND	ND	0.2	ND
5/3/03	Earring	Rome *	87.0	9.0	3.0	ND	ND	ND	ND
10/30/97	Earring	Rome *	99.1	0.6	ND	ND	ND	0.2	ND
38/6/08	Jewelry Piece	Rome *	68.6	25.7	3.3	2.2	ND	ND	ND
21/9/84	Bracelet	-	51.8	43.7	1.8	ND	ND	ND	2.4

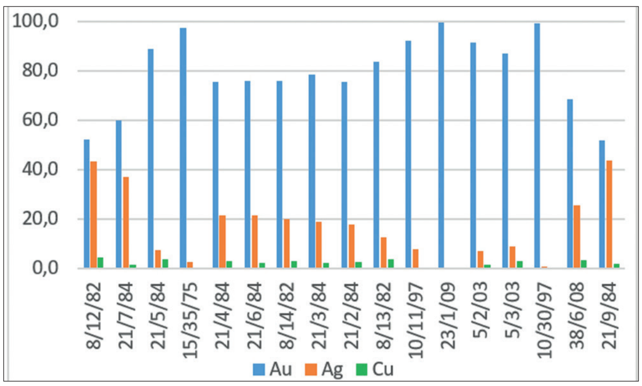

Figure 3: Basic elements detected in artifacts (%). / *Eserlerde tespit edilen temel elementler (%).*

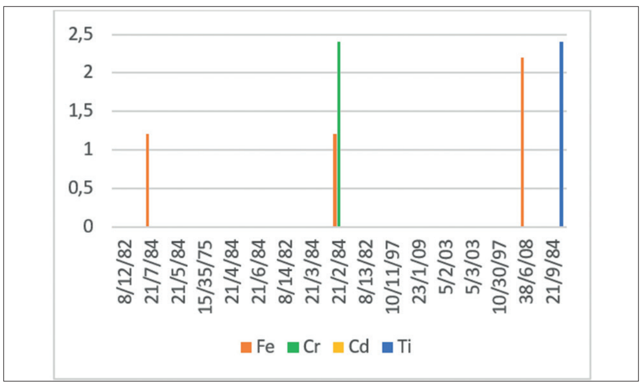

Figure 4: Few and trace amounts of elements detected in artifacts (%.) / *Eserlerde tespit edilen az ve iz elementler (%.)*

The artifacts studied are divided into 2 groups according to the period in which they were made, looking at the results of the analysis and the distribution of elements. In addition, one bracelet, which cannot be dated, was examined as a different group. Group 1 includes artifacts from the 8th-7th century BC and 7th century BC, Group 2 consists of artifacts from the Roman period, and finally Group 3 consists of 1 un-dated bracelet.

ANALYSIS OF 8th-7th CENTURY BC AND 7th CENTURY GOLD JEWELRY

A total of 10 pieces of jewelry examined within the scope of the study constitute this group. As a result of inventory and catalog scans, the artifacts were dated to the 8th-7th century and 7th centuries BC. When the artifacts were examined as forms, it was determined that they were all earrings but they were identified as different objects in the inventory records.

Table 4: P-EDXRF analysis results of 8th-7th century BC and 7th century artifacts (%). / *M.Ö. 8.-7. yüzyıl ve 7. yüzyıl eserlerinin p-EDXRF analiz sonuçları (%).*

Inventory Number	Explanation	Period	Au	Ag	Cu	Fe	Cr
8/12/82	Earring	8th -7th century BC**	52.2	43.4	4.4	ND	ND
21/7/84	Earring	8th -7th century BC**	60.1	37	1.5	1.2	ND
21/5/84	Earring	7th century BC **	88.6	7.4	3.8	ND	ND
15/35/75	Earring	7th century BC **	97.2	2.7	ND	ND	ND
21/4/84	Earring	7th century BC **	75.4	21.6	2.9	ND	ND
21/6/84	Earring	7th century BC **	75.8	21.6	2.4	ND	ND
8/14/82	Earring	7th century BC **	76	20	3	ND	ND
21/3/84	Earring	7th century BC **	78.5	18.9	2.4	ND	ND
21/2/84	Earring	7th century BC **	75.5	17.8	2.8	1.2	2.4
8/13/82	Earring	7th century BC **	83.4	12.6	3.8	ND	ND

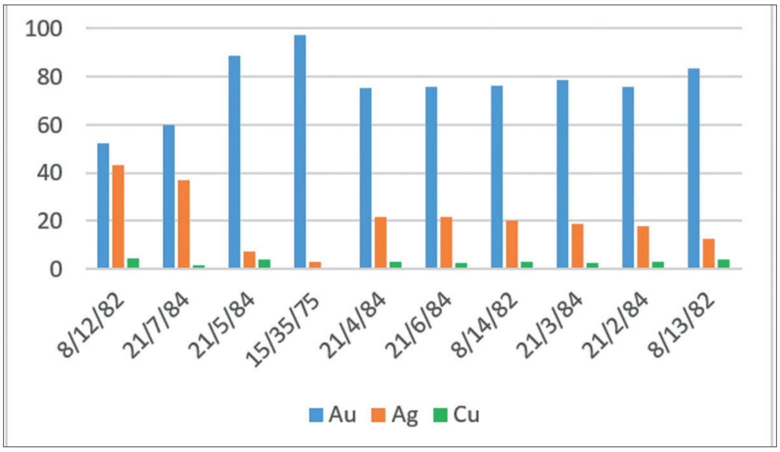

Figure 5: Basic elements identified in artifacts of the 8th-7th and 7th centuries BC (%). / *MÖ. 8.-7. ve 7. yüzyıl eserlerinde tespit edilen temel elementler (%).*

But no sign of the existence of refineries has been found. For this reason, it strengthened the possibility that gold separation was done by salt cementation (separation of gold and silver using salt) during this period (Melcher et al. 2009). In addition to this theory, the works, which are dated to an earlier period than the first half of the 6th century BC and are pure gold, may have been made of gold ore found in pure form in nature. Artifacts other than this artifact are made of natural electrum. Iron (Plate 1.2) was found in work 21/7/84 and iron and chromium (Plate 1.9) was found in work 21/2/84 as a few and trace element (Figure 6). When plates 1.2 and 1.9 are examined, it is clear that the iron in the artifact has been caused by surface pollution. Due to a lack of knowledge in the second half of the purification process of gold, the masters discovered naturally in nature gold + silver + copper mixture electrum because of its color and the precious metal used in the making

After the analysis, looking at the chemical composition of the artifacts, it was determined that they consist of gold, silver, and copper. Looking at the overall gold ratios, in terms of average rates; gold is 76.2%, silver is 20.3% and copper is 3%. When the artifact numbered 15/35/75 has been examined, it has been found that it is an alloy of gold and silver, unlike the artifacts in the group, and the ratio of gold is 97.2%. It has been thought that this artifact may have been made of natural gold ore (Table 4; Figure 5). A similar study, chemical analysis of the Gold finds of the Temple of Artemis of Ephesus, dated to the second half of the 7th century BC and the first half of the 6th century, found artifacts close to pure gold. The process of gold and silver purification is not yet known in the date period when these artifacts were made, which led scientists working in the Temple of Artemis of Ephesus to suggest that there may be gold purification refineries in the ancient city of Ephesus, as in Sardes.

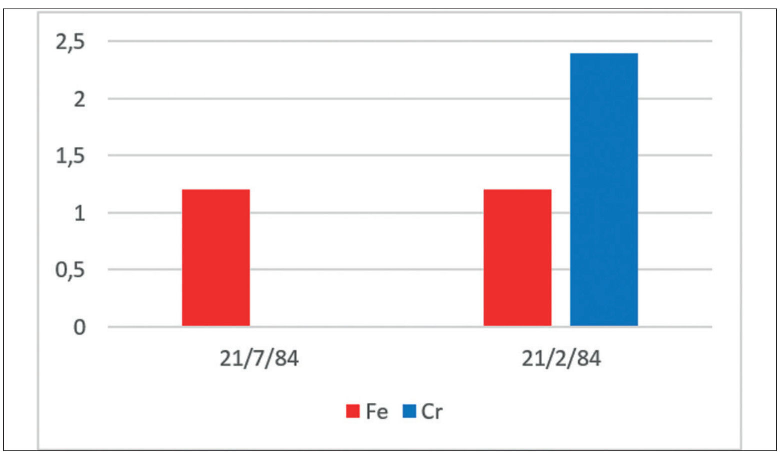

Figure 6: The few and trace elements identified in the artifacts of the 8th-7th century BC and the 7th century BC (%). / *MÖ. 8.-7. yüzyıl ve 7. yüzyıl eserlerinde tespit edilen az ve iz elementler (%)*

Table 5: P-EDXRF analysis results of Roman Period artifacts (%). / *Roma Dönemi eserlerinin p-EDXRF analiz sonuçları (%).*

Inventory Number	Explanation	Period	Au	Ag	Cu	Fe	Cd
10/11/97	Ring	Rome	92.1	7.8	ND	ND	ND
23/1/09	Ring	Rome	99.5	0.5	ND	ND	ND
5/2/03	Earring	Rome	91.4	6.9	1.4	ND	0.2
5/3/03	Earring	Rome	87	9	3	ND	ND
10/30/97	Earring	Rome	99.1	0.6	ND	ND	0.2
38/6/08	Jewelry Piece	Rome	68.6	25.7	3.3	2.2	ND

of jewelry. In other words, the alloys examined are consistent with the known technology of the time period in which they were produced.

ANALYSIS OF ROMAN PERIOD GOLD JEWELRY

This group is made up of 6 pieces of jewelry from the working group. The artifacts have been dated to the Roman period as a result of inventory and catalog scans. When the artifacts are examined as forms, they are two rings, three earrings, and one piece of jewelry.

Gold + silver and gold + silver + copper alloy has been identified when the results of the analysis have been examined. Iron and cadmium have been found as few and trace elements. It is believed that these few and trace elements are caused by substances that have been used for the purpose of surface pollution or surface cleaning (Table 5 - Figure 7). Apart from these alloys, it was found in works numbered 23/1/09 (plate 1.12) and 10/30/97 (plate 1.15), which are made of pure gold. The discovery of the gold purification process (Ramage and Craddock 2000), known to have been carried out in Sardes since the first half of the 6th century BC, led to a revolution in the art of jewelry, which allowed control of the proportions of gold, silver, and copper in gold artifacts. Along with this control, it was observed that the gold ratio was kept high in the production of gold artifacts. Although pure gold is a soft and easy-to-process mine, it is difficult to maintain the form it receives after processing. As a result, silver and copper were added to gold jewelry in order for it to be hard and retain its form.

The color of the jewelry is affected by the addition of metals. However, if all of these metals participate equally, there will be no color change. When the silver-to-gold ratio is increased, the color changes to green, and when copper is added, the color changes to red (Jewelry Technology - Alloy Metal Ratios, 2011).

Similar chemical compositions (Au+Ag, Au+Ag+Cu; Buccolieri et al 2017: Table 1) have been found in general, comparing chemical composition of studied jewelries with the archaeometric results of gold jewelry dated to the Roman and Hellenistic periods preserved in the Museum of Italy/Taranto, are quite similar to each others. In addition, although the difficulty of using artifacts that are pure gold has aroused the idea that they

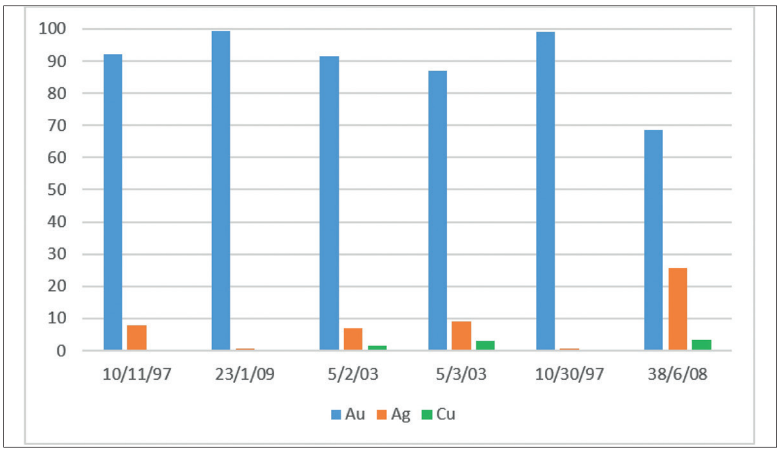

Figure 7: Basic elements identified in Roman Period artifacts (%). / *Roma Dönemi eserlerinde tespit edilen temel elementler (%)*

may be imitation (Inventory No.: 54451 (ring), 12036 (earring); Buccolieri et al, 2017: Table 1), the presence of artifacts in pure gold among the artifacts analyzed in the Taranto Museum has somewhat reduced this suspicion. The presence of artifacts in pure gold indicates that the artifacts have been extensively used in gold purification rather than in the use of pure gold ore.

Another comparison has been made with the results in the database created by Assoc. Prof. Dr. Mahmut AYDIN after the PEDXRF analysis of the Hellenistic and Roman period artifacts obtained after systematic excavations in different museums. Compared to the results of the analysis, the chemical content of the artifacts was found to be similar (Figure 8,9).

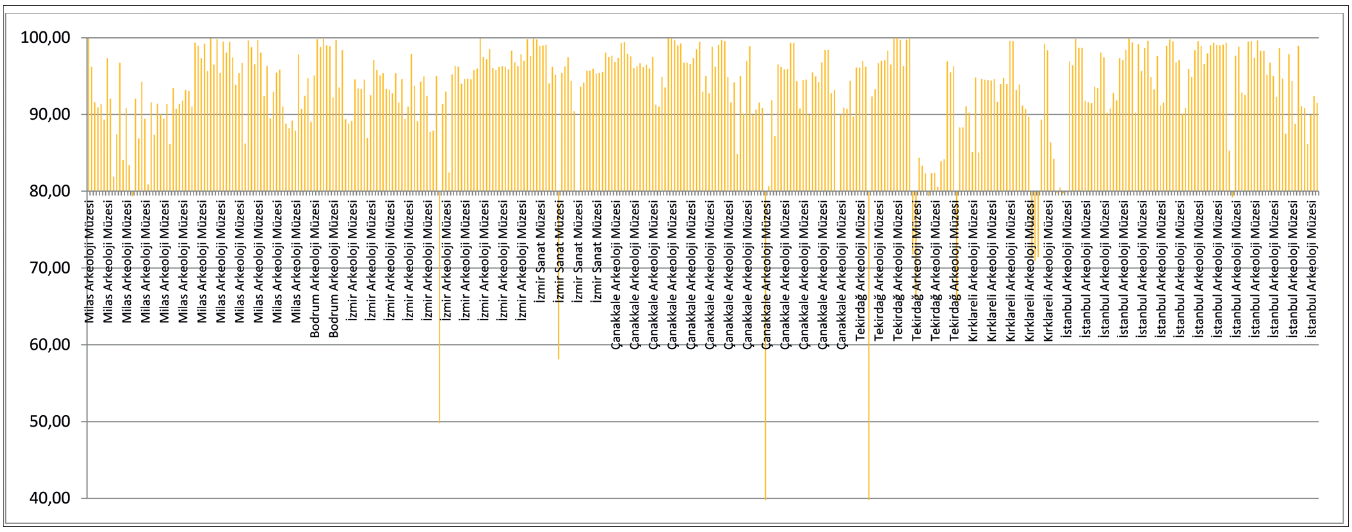

Figure 8: Au element analysis of gold artifacts recovered from excavations created by Assoc.Prof.Dr. Mahmut AYDIN (%). / *Doç.Dr. Mahmut AYDIN'ın oluşturduğu kazılardan ele geçen altın eserlerin Au elementi analiz sonucu (%).*

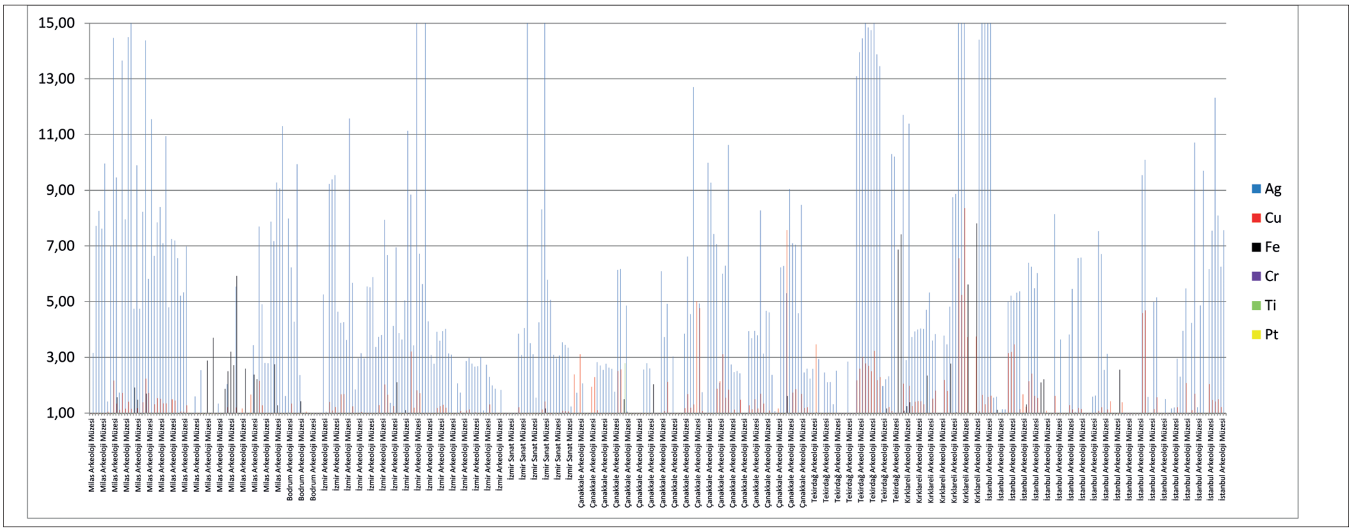

Figure 9: Ag, Cu, Fr, Cr, Ti elements ratios in the analysis results of Hellenistic and Roman gold artifacts recovered from excavations created by Assoc.Prof.Dr. Mahmut AYDIN (%). / *Doç.Dr. Mahmut AYDIN'ın oluşturduğu, kazılardan ele geçen Helenistik ve Roma Dönemi altın eserlerin analiz sonuçları Ag, Cu, Fe, Cr. Ti element oranları (%).*

Bracelet

Among the artifacts that have been studied is one bracelet. The artifact could not be dated after inventory records and catalog scans. The artifact's front and back sides have been examined separately. According to the results of the analysis, the artifact contains an average of 51.8 % gold, 43.7 % silver, and 1.8 % copper. In addition, titanium (Ti) has been found on both sides of the artifact (inner surface: 4.3% and outer surface: 0.6%) (Table 6; Plate 1.17 a,b). It has been detected especially on the inner surface, that is, in the intervening area. For this reason, it was believed that titanium originated from adhesives that were used during restoration and conservation work on the artifact. When examining the work, its

Table 6: P-EDXRF analysis results of the inventory numbered bracelet 21/9/84 (%). / *21/9/84 envanter numaralı bileziğin p-EDXRF analiz sonuçları (%).*

Katalog No	Inventory Number	Explanation	Period	Au	Ag	Cu	Ti
27	21/9/84	Bracelet (Inner surface)		50.8	42.9	1.8	4.3
27	21/9/84	Bracelet (Exterior surface)		52.9	44.5	1.8	0.6

thickness was 0.1 cm, and it was thought that this thickness was a thickness that would not allow the work to be used as a bracelet. It was thought that the work may be a coating material made to cover a bracelet that is made of a different metal for the purpose of coating technique by mechanical methods rather than a bracelet (E. Gündem 2020). Chemical analysis results of the gold bracelets in the Taranto Museum have not been similar compared to the chemical composition of the undateable bracelet in the study, and the overall gold average of the Roman and Hellenistic bracelets was 96.4%, silver 1.5% and copper 2% (Inventory No.: 6432- 54118-6432; Buccolieri et al. 2017: Table 1).

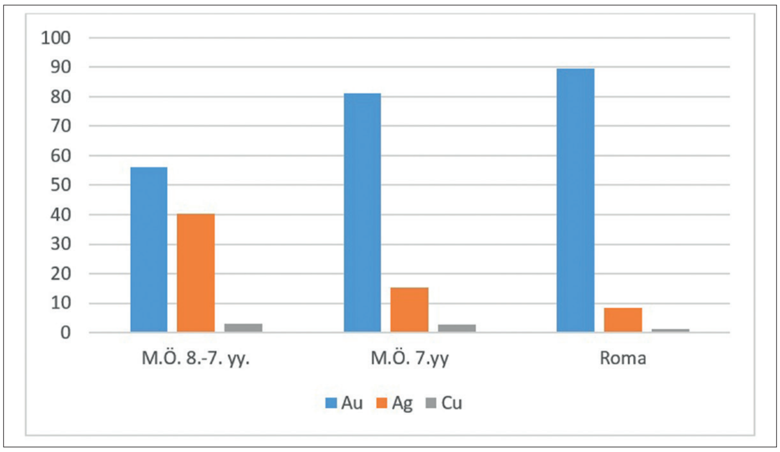

Figure 10: Comparison of the basic elements of gold, silver and copper found in all studied jewelry (%). / *Çalışılmış bütün takılarda bulunan altın, gümüş ve bakır temel elementlerinin karşılaştırılması (%).*

Finally, the general compositions of the 1st group and 2nd group works, which were separated periodically, were compared among themselves. Gold, silver, and copper ratios have been taken into account in these comparisons. In the tables created, it can be seen that the works dated between the 8th and 7th centuries BC have an overall gold ratios of 56.1%, a silver average of 40.2% and a copper average of 2.9%. The overall gold average of artifacts dated to the 7th century BC is 81.3%, the silver average is 15.3% and the copper average is 2.6%. The overall gold average of Roman artifacts is 89.6%, the silver average is 8.4% and the copper average is 1.2%. As we have come to more recent periods, the ratio of gold in the artifact has been increased, and on the other hand, the ratio of silver and copper has been reduced (Figure 10).

Correlations

		Au	Ag	Cu
Au	Pearson Correlation	1	**-0.992****	-0.393
	Sig. (2-tailed)		0.000	0.261
	N	10	10	10
Ag	Pearson Correlation	-0.992**	1	0.315
	Sig. (2-tailed)	0.000		0.375
	N	10	10	10
Cu	Pearson Correlation	-0.393	0.315	1
	Sig. (2-tailed)	0.261	0.375	
	N	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 11: Correlation rates of electrum jewelry analyzed with P-EDXRF in this study. / *Bu çalışmada P-EDXRF ile analiz edilen elektrum takıların korelasyon oranları.*

These findings are also evident in the analysis results of Assoc. Prof. Dr. Mahmut AYDIN (unpublished databank). It was assumed that the use of gold was greater in Roman-period gold artifacts, which is related to the fact that the process of purifying artifacts is known (Figure 8,9).

Correlations

		Cu	Au	Ag
Cu	Pearson Correlation	1	-0.389**	0.258**
	Sig. (2-tailed)		0.000	0.010
	N	99	99	99
Au	Pearson Correlation	-.389**	1	**-0.978****
	Sig. (2-tailed)	0.000		0.000
	N	99	99	99
Ag	Pearson Correlation	0.258**	-0.978**	1
	Sig. (2-tailed)	0.010	0.000	
	N	99	99	99

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 12: Correlation rates of Lydian period pure gold and electrum jewelry and objects (Created from Assoc Prof. Dr. Mahmut AYDIN's data.) / *Lidya Dönemi saf altın ve elektrum takı ve objelerin korelasyon oranları (Doç.Dr. Mahmut AYDIN'ın datalarından oluşturulmuştur).*

Statistical Analysis

SPSS 17.0 was used to create statistical tables of gold and electrum jewelry that were the subject of this study, as well as data sets created by Assoc. Prof.Dr. Mahmut AYDIN using the P-EDXRF analysis method from various museums in Turkey. Correlation rates between elements were determined using SPSS 17.0. Since correlation rates occur as a result of the artefact production technique, the analogy rates of the analyses conducted in this study with previous studies conducted by the same method are revealed.

In this study, the works are divided into two groups: works of the 7^{th}-8^{th} century BC and works of the Roman period. Correlation ratios of the first group of works are shown in Figure 11, and comparison studies are shown in Figure 12.

Correlations				
		Au	Ag	Cu
Au	Pearson Correlation	1	**-0.995****	**-0.850***
	Sig. (2-tailed)		0.000	0.032
	N	6	6	6
Ag	Pearson Correlation	-0.995**	1	0.794
	Sig. (2-tailed)	.000		0.059
	N	6	6	6
Cu	Pearson Correlation	-0.850*	0.794	1
	Sig. (2-tailed)	.032	.059	
	N	6	6	6

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 13: Correlation rates of jewelry analyzed with P-EDXRF within the scope of this study. / *Bu çalışma kapsamında P-EDXRF ile analiz edilen takıların korelasyon oranları.*

Correlations				
		Au	Ag	Cu
Au	Pearson Correlation	1	**-0.967****	-0.436**
	Sig. (2-tailed)		0.000	0.000
	N	254	254	254
Ag	Pearson Correlation	-0.967**	1	0.259**
	Sig. (2-tailed)	0.000		0.000
	N	254	254	254
Cu	Pearson Correlation	-.436**	0.259**	1
	Sig. (2-tailed)	0.000	0.000	
	N	254	254	254

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 14: Correlation rates of Roman period gold jewelry and objects analyzed with P-EDXRF (created from the unpublished databank of Assoc. Prof. Dr. Mahmut AYDIN). / *P-EDXRF ile analiz edilmiş Roma dönemi altın takı ve objelerin korelasyon oranları (Doç.Dr. Mahmut AYDIN'ın datalarından oluşturulmuştur).*

Looking at the correlation rates of electrum jewelry in Figure 11. a ratio of -0.992 was found. indicating an excellent negative correlation between gold and silver. This ratio means that silver was used instead of gold in jewelry where the ratio of gold was reduced. This ratio concludes with the correlation rates of Lydian period gold jewelery obtained from excavations that are contemporaneous with the works studied in this article and analyzed with P-EDXRF but not published by Assoc. Prof. Dr. Mahmut AYDIN (unpublished databank) with a difference of -0.978 to 1%.

Correlation Rates of Roman Period Jewelry

Looking at the correlation results of the Roman jewelry analyses that are the subject of this study it was found that there was a negative correlation between gold and silver in the same proportions (-0.995) as in the works of the 6th-7th century BC (Figure 13). The correlation rates of gold and silver in this study are also very close to the correlation rates of 254 gold jewelry -0.967. which Assoc. Prof. Dr. Mahmut AYDIN analyzed with P-EDXRF (Figure 14). According to early gold jewelry. there are differences in the correlation rates between gold and copper in Roman gold jewelry. Correlation rates between gold and copper in early jewelry (see correlation rates between gold and copper Figure 11.12) while **-0.393**. it increased to **-0.850** in Roman Period Jewelry. This. in turn. indicates that during the Roman period. the ratios of silver and copper increased while the ratio of gold decreased.

CONCLUSION

As a result of the analyses and comparisons with similar studies. we conclude that gold jewelry made in the 8th-7th centuries BC. the 7th century BC and the Roman period has generally been produced in three different compositions; the first is pure gold artifacts. the second is gold + silver. and the third is gold + silver + copper alloy. Since the discovery of the gold purification process. gold jewelry artifacts of various forms and functions have been produced from pure gold. and while it is difficult to use. it has been consciously preferred rather than by chance. Periodically. it has been determined that alloys and correlations (especially gold-silver and copper correlations) do not change at a significant rate. but the gold. silver. and copper ratio does. SPSS correlation rates in the artifacts demonstrate that there is a negative correlation of up to 99% between gold and silver. and this does not change over time. This means that when the gold-to-silver ratio was reduced in the ancient tradition of gold jewelry production. silver has been used instead of the reduced ratio. It has also been discovered that the golden ratio in Roman gold jewelry was located in the alloy to a greater extent than in previous periods.

With the discovery of the gold mine. it has been observed that the making and use of gold jewelry exists in every age and society. The advancement of this manufacturing technology. as well as the skillful application of these technologies. has demonstrated that it diversifies existing alloys. Our country is rich in artistic and cultural heritage. The preservation of these treasures. as well as the determination of their chemical composition while they are protected and archived in museums. as well as the recording of the results obtained and the establishment of data banks. are a requirement of our time. It has been determined that with the creation of these data banks. more information about the evolution of jewelry craftsmanship and the use of periodic technology can be provided. as well as that these data banks can provide museums with auxiliary data for dating artifacts that have been acquired by purchase and cannot be dated.

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