NON-INVASIVE ANALYSIS OF A GOLD PECTORAL, WITH A PAIR OF BIRD-SHAPED FIBULAE AND PENDANTS, FROM THE COLLECTION OF THE ARCHAEOLOGICAL MUSEUM IN ZAGREB

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This paper discusses the results of XRF measurements taken on the gold pectoral acquired by the Archaeological Museum in Zagreb in 1933 from Bosnia and Herzegovina. The analysis shows that the pectoral is a pastiche of sorts, consisting of newer components specifically produced for the pectoral (fibulae, chain and central pendant), and older ones (two-part pendants and associated beads) probably recycled from pre-existing necklaces. The production centre, hypothetically located in the eastern Adriatic or the western Balkans, had access to various qualities of gold alloys, Asian and Portuguese garnets, and HIMT glass. Despite the similarities to the finds from the 1890 sarcophagus in Potoci, it remains inconclusive whether this pectoral is directly related to the discoveries from the 1882 sarcophagus in the same location.

Key words:
gold, garnet, glass, pectoral, bird-shaped fibulae, 5th – 6th c., non-invasive analysis, XRF, Potoci, Bosnia and Herzegovina, Archaeological Museum in Zagreb

FIGURE 1. A) Pectoral with a pair of bird-shaped fibulae and pendants (photo by I. Krajcar).

Introduction

A gold pectoral with bird-shaped fibulae and a chain with five pendants was purchased from Grga Smoljan of Mostar, in Bosnia and Herzegovina, in 1933 for the Archaeological Museum in Zagreb[1] and became an item of the Museum's Medieval Collection (Fig. 1: a–b).[2] The pectoral consists of a pair of fibulae, each in the shape of a bird of prey, connected by a loop-in-loop chain on which five pendants are suspended at regular intervals. The birds of prey are shown with closed wings, and are framed with pseudo-filigree wire. Their accentuated downward-curved beaks are displayed from the right side, decorated with flat-cut garnet and green glass inlays in densely-arranged cells that form the head with an eye, beak, neck, right wing, breast and tail of the bird. A cross-hatched foil decoration can be seen below the flat-cut garnet inlays, but only on the left fibula. Gold needle holders and a fastening mechanism are soldered on the smooth rear surface of the fibulae. The central pendant consists of a barrel-shaped (probably ribbed) gold foil bead with a wire passing through, and a leaf-shaped pendant decorated with flat-cut garnets arranged in three cells, around which a pseudo-filigree wire is attached. Two pendants are suspended on each side of the central pendant at equal intervals. The pendants are made of a barrel-shaped gold foil bead through which a wire is threaded, making it into a two-part pendant composed of an upper, smaller round cell, and a lower, larger oval cell, both with a single cabochon. The back plate of each pendant is decorated with a carved motif of pine branches, seen on both sides of the plate, while the rear of the central pendant is smooth. The barrel-shaped beads have a surface that is smooth or ribbed: two beads are ribbed, one is quite worn but probably has a ribbed surface, one smooth, and one is damaged, and therefore its surface cannot be defined. The flat-cut garnet decorating the bird's wing is missing on the right fibula, as well as both garnets on the two outer side pendants, and the lower flat-cut glass or garnet on the central pendant. Both fibulae are missing the copper-alloy pins, currently visible only as remains of green corrosion marking their original position. A green trace of corrosion is also visible on the repair of the rear of the upper part of the left fibula, which was made by adding a silver sheet with a new silver pin holder.[3]

This stray find (as the seller never mentioned a place of discovery) is well known in archaeological literature from its first publication in 1954.[4] Zdenko Vinski defined it as a piece of female jewellery of the Ostrogoths and dated it to the first four

1 "Kupili smo od Smoljan Grga Mostar jedan zlatni lanac iz ranijeg sred. vjeka s privjescima i uloščima od crv. stakla za 2000 d. / We bought from Smoljan Grga, Mostar, a gold chain from the early middle ages with pendants and inlays of red glass for 2000 d.". Main inventory book AMZ, 22, no. 84 (26 May 1933).

2 Inv. no. S-3371.

3 Demo 2014, 28 (an extensive and detailed description of the pectoral). Dimensions: length 21 cm; length of the fibulae 2.6 cm; length of the middle pendant 2.8 cm; length of the side pendants (max.) 3.7 cm; weight 22.181 g.

4 Vinski 1954, 307–313, Abb. 1.

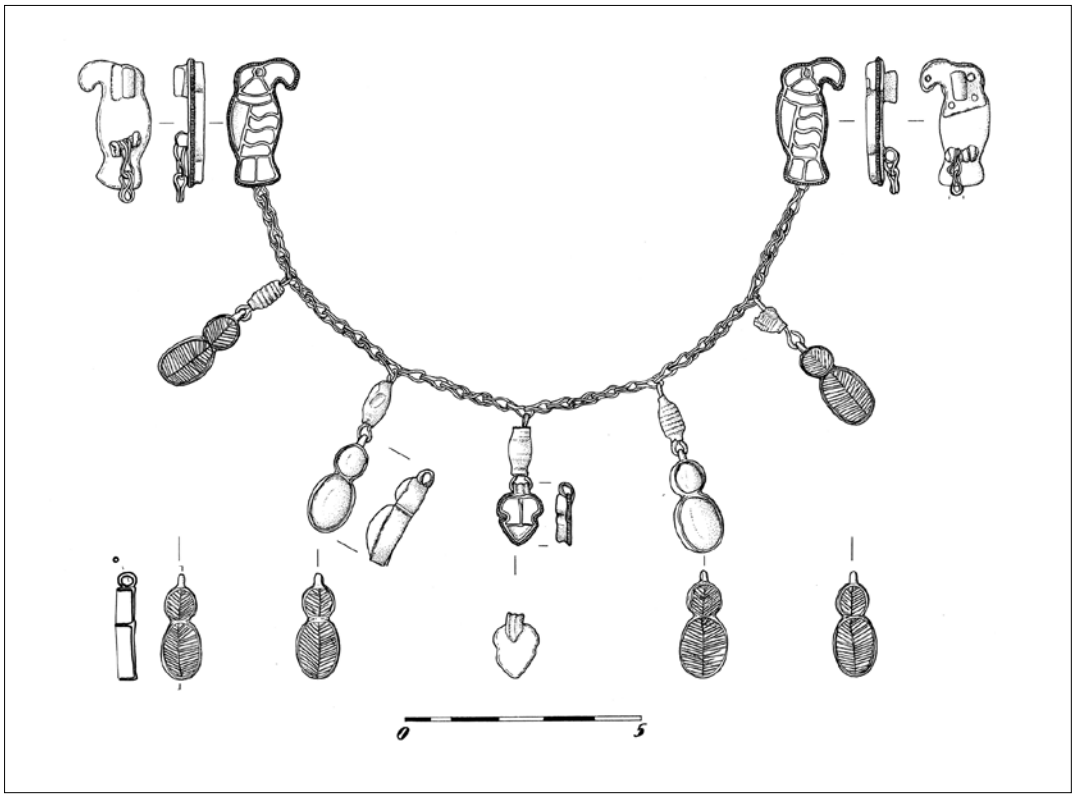

FIGURE 1. B) Drawing of the pectoral (made by A. Dugonjić).

decades of the 6th century. In the same article, he compared the pectoral with finds from the (Han-) Potoci site near Mostar, originating from sarcophagus burials with gold items discovered in 1890,[5] and, explaining his assumption, stated that the pectoral came from the same site.[6] From this publication onwards this pectoral has been known in the literature as the "pectoral from Potoci".[7]

Context of the Potoci find

Potoci, a village in the *Bijelo polje* basin, is located approximately ten kilometres north of Mostar, in Bosnia and Herzegovina (Map). Local inhabitants discovered a sarcophagus in 1882 at the nearby military barracks of the gendarmerie (*kasarna*), and alienated all items from the site.[8] Another, smaller, sarcophagus was found in 1890; the items were also collected by locals but then given to a person of trust from the National Museum of Bosnia and Herzegovina.[9] A female child was buried in the second sarcophagus with a pair of gold earrings with a bead made of openwork filigree on a gold hoop, and a round- and drop-shaped pendant with green glass and garnet inlays (Fig. 2: a). Alongside the earrings, the burial included a necklace consisting of four gold tubular beads and one spherical garnet bead (Fig. 2: b), a pair of gilded silver bow fibulae (Fig. 2: c), and a copper-alloy amulet box (Fig. 2: d).[10]

The fibulae from Potoci each have a semi-circular head-plate decorated with two opposite spirals framed with five knobs, and a rhomboidal foot-plate ending in a zoomorphic knob, while the corners of the short diagonal are marked by two circular cabochon-cut garnets. The foot-plate decoration is unique: above a triangular motif there is a line of three closed U-shaped motifs.

5 Radimský 1890, 337–342; 1893, 307–313.

6 Vinski 1954, 307–313.

7 The bibliography mentions the names *Han-Potoci*, *Potoci han* and *Potoci-Vrbe*, which describe the same location: that is, the place where the pectoral was supposedly found. For the literature concerning the pectoral, see Demo 2014, 28.

8 The number and type of finds from the first sarcophagus are unknown; Radimský states that the local workers mentioned gold objects, rings and one metal box, but which were taken by a gendarmerie officer soon after the discovery of the sarcophagus (Radimský 1890, 340).

9 Radimský 1890, 337–342; 1893, 307–313; Vinski 1954, 307–313.

10 Radimský 1890, 337–342; 1893, 307–313; Vinski 1954, 307–313; Uglešić 1990, 212–213, 221–224, T.1: 1, 6: 1–2, 7: 5–6, 8: 2–3; Zemaljski muzej Bosne i Hercegovine 2008, 42. The collection of the National Museum of Bosnia and Herzegovina holds only one fibula, since one had been kept by the finder in 1890 (Radimský 1890, 338). In the literature, the fibulae are most often published as a pair, with an accompanying drawing, but without information about the location of the second fibula. Werner first wrote in 1950 that the fibula and bulla are kept at the *Naturhistorisches Museum* in Vienna, but he made a mistake, since the bulla is, and was then, in Sarajevo. The fibula was sold to the NHM in 1905 as a part of Hugo Jedlička's collection. In the amulet box (bulla), there were two amber beads, which remained unpublished. Previous literature described the amulet box as silver. However, recent conservation and restoration efforts at the National Museum of Bosnia and Herzegovina have revealed that the item is made of a copper alloy. We express our gratitude to curator Adisa Lepić of the National Museum of Bosnia and Herzegovina for all the information and photos provided, and to colleagues Stefan Eichert and Vinzenz Kern of the Natural History Museum Vienna for the information from their inventory.

MAP. Location of the Potoci site, Bosnia and Herzegovina (maps-for-free.com, adapted by P. Dugonjić).

The bow fibulae belong to the wide group of the Ponto-Danubian-Italian 'east Germanic' fibulae of the late 5th – 6th century. The unusual decoration of the foot-plate finds some analogies (that is, for the concentric triangular pattern on its upper part) among bow brooches from Dalmatia; two further examples are known, one from Northern Gaul and another from an unknown location.[11] The proportions between head-plate, bow and foot-plate, as well as the weakly profiled zoomorphic ending of the foot-plate, however, find their best counterparts in the Middle Danube region, especially among the fibulae of type Mistřín, with which the Potoci fibulae also share the decoration of the head-plate and, in some cases, the presence of five headknobs.[12] On the basis of this comparison, the Potoci fibulae should be interpreted as an Adriatic type deriving from the Mistřín and/or other related Danubian types, and therefore dated to the late 5th century or early 6th.

Similar round copper-alloy amulet boxes have been found in early-to-late 6th-century graves in Central Spain,[13] in the Mediterranean area and beyond.[14] The earrings with drop-shaped inlaid pendants have found no exact parallels; they can, however, be regarded as less complex counterparts of the cloisonné-decorated examples from rich deposits of the late 5th century and early 6th, such as Reggio Emilia, Capena and Domagnano in Italy, and Varna, Olbia and Džurga-Oba in the Black Sea region.[15] A vague resemblance is also shown by an earring with a pendant consisting of two inlaid garnets found at the St Sofia basilica in Sofia.[16] The two Bulgarian earrings (Sofia and Varna) display hook closures, a feature shared by the Potoci earrings as well; a combination of hook closures and gold beads can be observed in a pair of earrings from the Zeccone treasure (Northern Italy), deposited after 476 AD.[17] None of the examples mentioned, however, displays a bead in openwork filigree. A morphological

11 Belošević 1965, 130–134, T. 1: 1–2; Bierbrauer 1975, 97–98, 239–240, 354, n. 34, Pl. 65: 1, 3–4.

12 Koch 1998, 249–251; Tejral 2002, 321–325. The Potoci fibula or fibulae (see note 10) are published and chronologically typologized in: Radimský 1890, 341, sl. 6; 1893, 306, Fig. 6; Vinski 1954, 309, Abb. 2: 2; Miletić 1955, 152–153, sl. 2: a; 1963, 50, cat. no. 197; 1978, 100, Fig. 4; Kovačević 1960, 22–23, sl. 31; Bierbrauer 1975, 73, sl. 9: 1–2, Taf. 73: 2; Mrkobrad 1980, 28, n. 134, T. 13: 4, 6; Uglešić 1990, 212–213, T. 6: 1–2; 2003, 102–103, 124, T. 4: 3–4.

13 Taracena 1921, 24, 27–28, Pl. 15; Fernández Godín, Pérez de Barradas 1931, 5, lám. 5–6; Ripoll López 1985, 102–106, Fig. 29; 1993 – 1994, 206–210, Fig. 11: 136; Sasse 2000, 210–223, Taf. 15: 136; Catalán Ramos, Rojas Rodríguez-Malo 2010, 229–230, Fig. 8; Arias Sánchez, Balmaseda Muncharaz 2015, 998–1010.

14 Vida 1995, 220–288.

15 Degani 1959, 64–65, tav. 26; Ross 1965, 117–119, Pl. 79–82; Bierbrauer 1973; 1975, 272–281, 302–309, Taf. 18–21, 32–33, 86; Bordenache Battaglia 1983, 147–151; Arena *et al.* 2001, 174–175, I.3.2; Ermolin 2012, 346, Fig. 5, 1–2. See also Quast 2002; Kazanski 2023.

16 Ruseva-Slokoska 1991, 120, cat. no. 42.

17 Peroni 1967, Pl. 11.

FIGURES 2. The assemblage of finds from the smaller sarcophagus found in 1890 (no scale; Archive of the National Museum of Bosnia and Herzegovina).

parallel for the Potoci openwork beads can be observed in a funerary deposit of the 5th century conserved at the National Museum of History in Sofia.[18]

The necklace beads, consisting of four tubular gold beads and one spherical garnet bead, may have been produced slightly earlier, not later than the middle of the 5th century, as suggested by combinations of similar beads recorded in the Black Sea region, Gaul and Africa.[19] Therefore, they may have been rather old objects at the time of their deposition.

The assemblage of goods seems to be rather coherent, corresponding to a rather rich jewellery kit consisting of a pair of earrings, a pair of fibulae, a necklace made of beads, and one amulet box. Similar combinations of objects are known in the late 5th and early 6th centuries, as shown by the graves at Domolospuszta and Répcelak in Pannonia, and at Ladendorf in Lower Austria, each one containing a pair of bow brooches, one or two earrings and necklace beads in gold foil (among other objects).[20] Similar objects are to be identified as well within the Reggio Emilia treasure.[21]

The items described above from the second burial in Potoci, discovered in later times, were the reason why Zdenko Vinski assumed that the pectoral came from the bigger, probably robbed, sarcophagus found in 1882.

However, regardless of the fact that Potoci is firmly rooted in the literature as the place where the pectoral was found, caution is required, because the pectoral had been acquired by the Archaeological Museum in Zagreb in 1933 – that is, half a century after the presumed discovery – and therefore we must emphasize that there is so far no solid evidence that the pectoral actually originates from Potoci.

18 Muzej Sofia 1995, 83, no. 149.

19 Bayard, Piton, Schuler 1981, 202, Pl. 20: 3; Koenig 1981, 308–312; Mahéo 1990, 310–311; Riha 1990, Pl. 76: 2949–2952; Eger 2001, 364–365, Abb. 5; Ermolin 2012, 346, Fig. 5; Mączyńska *et al.* 2016, 98–99, Pl. 13. See also Pinar Gil, Ripoll López 2008, 111–112, with further literature.

20 Dombay 1956; Windl 1997; Kiss 2001.

21 Degani 1959, tav. 30; Bierbrauer 1975, Taf. 32–33.

The question of authenticity and integrity

The uncertainties regarding the circumstances of the discovery and origin, together with its lack of exact parallels, cast some doubts about the authenticity and integrity of the pectoral. As Željko Demo has noticed, the typology of some components of the artefact suggests that it might bring together pieces that originated in different production centres.[22] As a matter of fact, four main groups of components can be recognized by the naked eye:

1. Items with flat cloisonné panels (bird-shaped fibulae and leaf-shaped pendant);
2. Loop-in-loop chain;
3. The two-part pendants with round and oval garnet inlays;
4. Beads in gold sheet.

Although all are well-attested forms in 5th- and 6th-century European jewellery, they have not been documented occurring together as components of a single artefact. Pairs of silver bird-shaped fibulae are occasionally attached to a silver chain, as shown by 6th-century examples such as Unterhaching, grave 10, and Weingarten, grave 119.[23] Gold versions of such combinations are rarer; and, as the example from Saint-Denis suggests, they may have been related to places of power and to exceptionally wealthy individuals.[24] A combination of gold bird-shaped cloisonné fibulae and a gold chain is attested in the 5th-century peacock-shaped fibulae of the Pietroasa treasure,[25] and can be hypothesized for the early 6th-century treasure of Domagnano, where a pair of big eagle-shaped fibulae feature rings that may have been connected by means of a gold chain.[26] Traces of similar outfits are to be seen in late 5th-century cloisonné bow fibulae, as in Desana and Villalta di Gazzo.[27] No trace of the chain has been preserved, however. On the basis of comparison with the somewhat earlier grave of Airan,[28] hosting a pair of garnet-inlaid bow fibulae, the chains connecting the fibulae may have been made of silver.

The pectoral's fibulae belong to the extensive group of small bird fibulae, widely attested in Northern Gaul, Southern Germany and the Elbe basin from the second half of the 5th century.[29] Bird fibulae with cloisonné decoration are particularly well attested during the last third of the 5th century and the first third of the 6th. The pectoral's fibulae, however, do not comfortably fit into any of the major types. A rather unusual feature is the combination of an oval body with the absence of claws, a feature that the pectoral's fibulae share with some examples found in Southern Germany (e.g. Straubing-Bajuwarenstraße, Altenerding, Unterhaching, Kleinlangheim, Eichstetten am Kaiserstuhl) and Northern Italy (Cividale – Cella-San Giovanni).[30] At least for the fibulae of Cividale and the pectoral, this feature may suggest a still blurry typological connection with early eagle-shaped fibulae, such as those from Novae, Oßmannstedt and Rome–via Flaminia,[31] dating from the late 5th century. In the case of the pectoral's fibulae, this observation seems to be confirmed by some stylistic similarities with the Novae fibula, such as the form of the bird's beak, the radial disposition of the head cells (a recurring feature on bird-shaped subjects in the Apahida jewellery style)[32] and the 'collar' separating head from breast; the latter feature is to be seen on the Oßmannstedt and Rome fibulae. Another feature connecting the pectoral's fibulae with this group of jewellery are the S-shaped cells in the bird's breast, finding parallels in the Apahida-style group, as well as in some fibulae of the late 5th and early 6th centuries found in Northern Italy (Desana) and Southern Germany (Straubing).[33]

As for the leaf-shaped pendant with flat cloisonné panels, two gold pendants from Lužice (grave 46) can be mentioned among the formally most similar parallels (leaf-shaped with flat-ground almandines in three cells), and were probably parts of a necklace of glass and amber beads with an additional round cloisonné pendant.[34] The grave is dated to the second third of the 6th century. Similar pendants, although with more complex cell patterns, have been recorded in graves found in South-Western Germany, such as Schwenningen or Bonn-Schwarzrheindorf;[35] the former is dated to the second quarter of the 6th century. The earliest examples of this morphologically heterogeneous group are to be found in deposits of the late 5th and early 6th centuries,[36] such as Domagnano and Nasobůrky, where they may have been associated with a composite pectoral (Domagnano) and a gold necklace with filigree pendants and a stone-inlaid clasp (Nasobůrky).[37] Two possible early pendants were found alongside a pair of square-headed relief fibulae at Nordendorf, grave 137/1844, displaying unusual typological features that can be attributed to the late 5th century or to the first half of the 6th.[38]

22 Demo 2014, 30.

23 Roth, Theune 1995, 37, Fig. 23, 31: A; Haas-Gebhard 2013, 102–103, Fig. 3, Pl. 8: 3–5.

24 Fleury, France-Lanord 1998, 234.

25 Odobescu 1896, 78–84; Schmauder 2002, 54–55, Taf. 101–105.

26 Bierbrauer 1973; 1975, 272–281, Pl. 18–21; Nawroth 2000.

27 Bierbrauer 1975, 263–272, Pl. 6–17; Possenti 2005; Aimone 2010, 66–72.

28 Robillard de Beaurepaire 1875; Salin, France-Lanord 1949; Pilet 1995; 2007.

29 Thiry 1939; Roth 1990; Haimerl 1998a; 1998b; Theune 2006.

30 Fuchs, Werner 1950, 34, 61, Taf. A; Peschek 1996, Taf. 51; Geisler 1998, Pl. 208: gr. 600: 1–2; Sasse 2001, 205, Taf. 76: gr. 182: 2; Losert, Pleterski 2003, Fig. 22: 6–10; Haas-Gebhard 2013, 102–103, Fig. 3, Pl. 8: 3–5.

31 Bierbrauer 1975, 309–313, Taf. 36; Timpel 1999; Genčeva 2003.

32 E.g. Tihelka 1963, 481–482, obr. 6: 2; Schmauder 2002, 14–15, Taf. 17, 20, 22 (Apahida II: scabbard fitting and horse-harness fittings); Jiřík 2023, Fig. 2.

33 Bierbrauer 1975, 263–272, Pl. 6; Geisler 1998, 387, Taf. 343; Schmauder 2002, Taf. 1: 1, 15: 1, 20: 16, 21: 19, 23: 23, 32: 1; Aimone 2010, 66–72; Jiřík 2023, Fig. 3.

34 Klanica, Klanicová 2011, 251–252, Taf. 48: 22–23, 121: 6, 8.

35 Christlein 1978, Pl. 48; Menghin (ed.) 2007, 541, cat. no. VII 48.34.

36 Koch 2012, 52.

37 Bierbrauer 1973; Tejral 1982, 206, obr. 46: 11. See also Prohászka 2008.

38 Trier 2002, 31, Taf. 105: 1–6.

The two-part pendants with round and oval garnet inlays do not find direct counterparts, except for the aforementioned earring from Sofia, attributed to the 3rd – 4th century.[39] Comparable individual inlays were, however, set in 5th-century Mediterranean jewels, as the earrings found in the deposits of Rome and, perhaps, Raciaria suggest.[40] The ground plate of the Potoci pendants shows a pine-branch pattern that finds good counterparts in 5th – 6th-century jewellery deposits from the Black Sea and Eastern Mediterranean and, to a lesser extent, from the Adriatic and the Carpathian basin.[41]

The barrel-shaped pendants in gold foil are widely attested as necklace beads throughout the Roman provinces during the 4th – 5th centuries, as observed in examples from Moesia, Pannonia, Raetia, Italy, Gaul and Spain.[42] Towards the end of the time span, in the late 5th century and the beginning of the 6th century, this type of bead is known in the central European barbaricum as well, as shown by several examples found in the Carpathian basin and north of the Middle Danube.[43] The specimens of the Potoci pectoral belong to at least two different types: as said, at least two beads display ribbed surfaces, whereas at least one is made in smooth gold foil.

It can therefore be assumed that the pectoral, in its preserved state, corresponds, at least partially, to a pastiche of sorts, bringing together components recycled from different jewels and, perhaps, also some pieces specifically produced for this purpose.[44]

This being established, the questions to be addressed are the time, place and modality in which the pectoral was assembled. The XRF analysis conducted in 2022 on the artefact contributes to shedding new light on the issue.

The XRF analysis

On June 2022, a campaign of non-invasive XRF analyses was launched by a team of the University of Hradec Králové (UHK),[45] in cooperation with the Archaeological Museum in Zagreb, National Museum of Slovenia, City Museum of Ljubljana, Gorenjski Museum in Kranj, and National Archaeological Museum in Cividale del Friuli, aiming at determining the chemical composition of gold jewels found within the boundaries of the Odoacrian/Ostrogothic kingdom (c. 476 – 526). Given the historical interest and the intrinsic value of the objects to be analysed, non-destructive methods needed to be applied. The strategy jointly developed by the UHK team and the MAIN group (University of Turin, Italy) decided to rely on a portable X-ray fluorescence operated by UHK to take *in situ* measurements of the objects. These raw data would subsequently be verified and elaborated by the MAIN group. The results on the pectoral from Potoci are an example of this research thread.

Energy resolution	150eV @ Ka of Mn
X-ray tube voltage	50kV
X-ray tube power	4W
Achievable X-ray lamp current	200uA

TABLE 1. Instrument details (made by A. M. Marko, A. Agostino).

X-ray fluorescence (XRF) spectrometry, a method used for elemental analysis, is non-destructive, fast and easy to use, requires minimal preparation of the samples, and allows for *in situ* analysis of the objects. XRF spectrometry uses a polychromatic beam produced from X-ray tubes of high-energy photons to induce the emission of characteristic lines due to the composition of the matrix of the object analysed.[46] A portable XRF spectrometer, model Olympus Vanta VCR, was used for the analysis (Tab. 1).

In order to match the data with the exact location of the measurements, we photographed the pectoral and assigned codes to each measured location (Figs 3–4). The metal parts were measured with the Alloy Plus setting, and the stone and glass inlays were measured with the Geochem setting. The collimator was set up to 3 mm in order to limit the area of analysis. In order to achieve complete measurements of lighter materials (especially garnets), a complementary series of measurements in the Geochem setting were taken without the collimator to improve the counting statistics.

All the spectra were processed with the commercial software Baxil (Brightspec NV/SA, Belgium), derived from the academic software QXAS (IAEA). To obtain the quantification of the elements, a mixed analysis algorithm was applied, involving the treatment of the matrix through a fundamental-parameter approach (FP) scaled on comparison with a series of standards that allows the peculiarities of portable instrumentation

39 Ruseva-Slokoska 1991, 120, cat. no. 42.

40 Ross 1965, 1–2, Pl. 1–4; Dzorzeti 1988, Fig. 8; Fiocchi Nicolai 2013, 63–64.

41 Barnea 1979, 228–229; Buora 1995, Fig. 1; Gerzen 1999; Schmidt 2004; Minčev 2009, 88–89; Ermolin 2012, 346, Fig. 5: 1–2; Demo 2014, 31, n. 11; Balogh 2018, 30–34; Schilling 2018.

42 On this type of bead, see Deppert-Lippitz 1997. Some examples: Moureau 1877 – 1898, Pl. 50; Paulovics 1927, Pl. 2; Keller 1971, Pl. 26; Vágó, Bóna 1976, Pl. 2, 4; Werner 1977, Pl. 111, 113; Rigaud da Sousa 1979; Ruseva-Slokoska 1991, 145, n. 112; Trésors archéologiques 1997, 100–101; Endrizzi 2002, Fig. 12, 34–35; Markov, Peeva 2003, 36, 39, Fig. 10; Filipović 2010, 47; Müller 2010, Pl. 77; Fiocchi Nicolai 2013, 65–66; Bassi 2015, 217–218, Fig. 8; Heras Mora, Olmedo Gragera 2015, 282–283, Fig. 15: 7.

43 Opreanu, Luca 2007, 566; Vágó (ed.) 2015, 400, 402; both with literature.

44 A good parallel from a certain archaeological context may be the pectoral from Beiral (early 5th century, Portugal: Rigaud da Sousa 1979), which brings together components of late Roman and Untersiebenbrunn-style jewellery. See Pinar Gil 2021, 80–81, on its interpretation as a 5th-century pastiche.

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46 Liritzis, Zacharias 2011, 110.

FIGURE 3. Map of the XRF measurements discussed in this paper: fibulae, chain and leaf-shaped pendant (made by J. Pinar Gil, A. M. Marko).

FIGURE 4. Map of the XRF measurements discussed in this paper: two-part garnet pendants and barrel-shaped beads (made by J. Pinar Gil, A. M. Marko).

	MgO	Al_2O_3	SiO_2	TiO_2	Cr_2O_3	MnO	FeO	CuO	CaO
nc1	10.1	19.4	38.4	0.0	0.8	0.9	26.3	0.7	3.4
nc2	12.3	21.9	40.1	0.0	0.5	0.8	22.5	0.3	1.6
nc3	11.1	21.4	39.3	0.0	0.4	0.9	25.1	0.2	1.6
nc4	9.8	20.6	40.1	0.5	0.0	0.5	27.1	0.0	1.4
nc5	7.8	19.3	42.8	0.0	0.7	1.3	24.3	0.4	3.4
nc6	13.1	21.5	38.3	0.5	0.0	0.1	23.4	0.0	3.1
nc7	8.3	18.7	46.3	0.0	0.5	0.8	21.5	0.9	2.9
nc8	11.0	22.3	40.5	0.0	0.4	0.7	23.9	0.3	0.9
nc9	10.6	21.8	40.2	0.0	0.5	1.0	24.6	0.3	1.0
nc10	5.1	19.7	41.4	0.0	0.4	0.5	29.2	0.6	3.0
nc11	11.0	20.6	38.0	0.4	0.0	0.3	25.9	0.2	3.7

TABLE 2. Chemical composition percentage wt/wt of the oxides present in the stones of the pectoral AMZ S-3371. Non-normalized values (made by A. Agostino).

	Au	Ag	Cu
Au_1	96.0	2.3	1.7
Au_1b	96.0	2.4	1.6
Au_2	82.2	16.8	1.1
Au_3	85.0	12.8	2.1
Au_4	85.0	12.9	2.1
Au_5	85.1	12.5	2.3
Au_6	87.3	12.0	0.7
Au_7	94.5	4.0	1.5
Au_8	82.9	15.0	2.1
Au_9	81.2	17.1	1.8
Au_10	84.2	11.7	4.1
Au_11	85.1	13.0	2.0
Au_12	92.3	6.0	1.6
Au_12b	92.7	5.9	1.4
Au_12c	95.6	3.5	0.9
Au_12d	95.3	3.7	1.1
Au_12e	95.5	3.6	0.9
Au_12f	94.7	4.1	1.2
Au_13	95.6	2.7	1.7
Au_13b	95.8	2.8	1.4

	Au	Ag	Cu
Au_14	96.5	2.4	1.2
Au_14b	94.7	2.2	3.1
Au_14c	95.0	2.2	2.8
Au_14e	20.4	0.5	74.1
Au_15	84.9	13.0	2.1
Au_15b	84.9	13.0	2.2
Au_16	84.8	13.1	2.1
Au_16b	84.7	13.2	2.2
Au_17	96.3	3.1	0.7
Au_17b	95.6	3.4	1.0
Au_18	84.9	12.9	2.2
Au_18b	84.8	13.0	2.2
Au_19	85.0	12.9	2.1
Au_19b	85.0	12.9	2.2
Au_20	3.0	92.6	3.9
Au_20b	4.9	80.6	12.9
Au_20c	92.0	3.9	4.1
Au_20d	49.2	1.7	45.1
Au_20e	31.9	1.1	65.0

TABLE 3. Chemical composition percentage wt/wt of elements present in the metal alloys of the pectoral AMZ S-3371. Non-normalized values (made by A. Agostino).

(NIST, SGT, CORNING, MBH certified reference materials) to be taken into account. Matrix interactions, as well as the effects of secondary fluorescence and self-absorption, have been considered in the use of a system of nonlinear equations and relative minimization of their correlation coefficients (De Jong).[47] The data are therefore to be considered quantitative, although attention must be paid to the representativeness of the same, because it is impossible to predict the different thicknesses of the patina layers (for metals) and any influences from the surface degradation (for the stones). In any case, the expected contribution of these interferences is to be considered within the measurement error that is prudently considered on the second decimal place.

All results have been subjected to a threshold of 0.01%, considered the detection limit (LLD) for all elements (for aluminium, 0.5% has been applied).[48] This is a prudential limit, since the instrumental sensitivity stands at tens of ppm (parts per million).[49] The results, expressed as absolute percentage weight of the volume analysed, are shown in Tables 2 and 3, divided according to the type of matrix (stones and metals).

Data correlation was achieved through a principal-component analysis (PCA) that used the Pearson coefficient to evaluate the placement of results in a two-dimensional representation of the set of variables (Figs 5–6).

Discussion

As shown, the composition of gold alloys shows two main groups: the first one is formed by the bird-shaped fibulae, the leaf-shaped pendant, and the chain linking them, displaying high percentages of Au, usually in the range 92 – 96%.

The other components of the alloy are also consistent, with silver content ranging from 2.5% to 6% (the highest values being on the chain) and with copper content ranging from 1% to 2%. The high copper value (4.1%) determined at point 20c (on the back of one of the bird-shaped fibulae) is due to a probable contamination caused during the application of the silver-alloy plate, whose composition is Ag 93% : Cu 4% : Au 3%. Likewise, points 14e and 20d–e mirror contaminations derived from the corrosion of the copper-alloy pins of both fibulae.

The second group corresponds to the barrel-shaped beads and the pendants. All these objects are characterized by an alloy composition showing a gold content around 85% and a silver content around 13%, with copper at a concentration of 2%. Some small compositional differences refer to the error caused by the rounded shape of some objects, for example the barrel-shaped beads, which in fact show a higher variability compared to the values reported above.

Although, with the available data, it is impossible to have a thorough discussion about the origin of the alloys, the compositional groupings and the archaeological typologies show a quite straightforward correspondence and provide some hints on the background of the manufacturing of the pectoral.

The gold alloys used in the objects decorated in flat-garnet cloisonné (bird-shaped fibulae and leaf-shaped pendant), as well as in the chain linking them, show remarkable affinities. Although such affinities may be explained in a number of ways (e.g. the wide use of gold coinage as a raw material), the arguably easiest explanation is that the main structural elements of the pectoral (fibulae and chain) were produced in a single production centre.[50] In addition to having access to high-quality gold, this hypothetical workshop would be characterized by its mastery of techniques such as cloisonné-inlaying and pseudo-filigree. These characteristics are also matched by the leaf-shaped pendant, which, as a central element in the pectoral's decoration, can be regarded as another of its main structural elements. It therefore appears likely that it may have been produced at the same place and attached to the pectoral at the same time as the fibulae and the chain.

The left fibula, however, appears to be a possible outlier in its group. From a technological viewpoint, it differs from both the right fibula and the leaf-shaped pendant in the presence of a cross-hatched foil set beneath the stone inlays; in addition, the repair visible on the back of the left fibula may be a witness to quite a long useful life. A parallel for the technological heterogeneity between the Potoci fibulae is to be found in the famous grave of the Frankish queen Aregund in Saint-Denis. Among other jewellery items, the queen was buried with two apparently identical cloisonné disc fibulae, linked to a gold chain. The fibulae, however, displayed technological and decorative discrepancies. Unlike the pectoral in Zagreb, however, these differences were associated with perceivable discrepancies in both the composition of the gold alloys and the provenance of the inlaid garnets, as PIXE analysis revealed. Accordingly, it has been convincingly hypothesized that one of the brooches was an original import from South-Western Germany, whereas the other was a local, high-quality imitation.[51] Neither the typological comparison of the pectoral's fibulae nor our recent non-invasive analysis explicitly supports any similar explanation: on the one hand, in view of the general absence of exact parallel finds and the uncertainty of the pectoral's provenance, the 'outlier fibula' can hardly be identified as an imported good; on the other hand, the compositions of metal, garnets and glass (see below in this section) in the two fibulae are very similar.

As said, the typology of the fibulae suggests a dating to the late decades of the 5th century or the early decades of the 6th, while the parallels of the pendant belong to the first two thirds of the 6th century. That suggests the first half of the 6th century as the

47 Jenkins 1995.

48 Rousseau, Willis, Duncan 1996.

49 Agostino, Falcone 2012.

50 Affinities in chemical composition have been useful for the reconstruction of jewellery sets formed by various objects found in 5th – 6th-century deposits, such as the Desana treasure (Aceto *et al.* 2023; Pinar Gil *et al.* 2023).

51 Périn, Calligaro 2005, 186–187, 194–195; Périn *et al.* 2012, 107–111.

most likely moment in which the production of the pectoral in its final form took place; this should be regarded as the time span in which the right fibula was made. This proposal would point out the Potoci pendant as one of the earliest examples of its type, together with the parallels of Nasobůrky, Domagnano and, perhaps, Nordendorf.

The pectoral was completed with gold components originating from at least one other source. The barrel-shaped beads probably serve as evidence for the recycling of older jewellery, as the peak of their use in bead necklaces lies within the late 4th century and the early 5th. The undecorated surfaces of some beads and the ribbed patterns on others suggest they may originally have belonged to at least two different jewellery sets (necklaces, bracelets). As for the two-part garnet pendants, the type cannot be dated within a short time span. Therefore, it is uncertain whether it was an older object at the time of the assemblage of the pectoral. The composition of the gold alloys, however, may suggest that not all these pendants were produced at the same time and/or place as the main structural components of the pectoral. Their chemical affinities could hypothetically be explained if this group of objects were to be interpreted as parts of jewels produced by a single workshop, probably different from the workshop responsible for the production of the fibulae and the chain. Comparable elements (oval garnet inlays and barrel-shaped gold beads) occur together in the jewellery deposits from the rich grave in Rome-Marcus Pope's basilica, although they certainly were not being used as a single jewellery set.[52] If our hypothesis, however, is to be accepted, the dating of the barrel-shaped beads would suggest that the components of this group of 'older' jewellery were integrated into the Potoci pectoral long after their date of production.

As for the non-metallic elements, the two inlays in green glass, corresponding to the filling of the 'collar' of the two bird-shaped fibulae (points 3 and 20), show quite comparable values, suggesting a common origin MgO/1.9_0.1%, Al2O3/4.5_0.2%, SiO2/60.8_2.1%, CaO/5.9_0.5%, TiO2/1.6_0.1%, MnO/1.7_0.1%, Fe2O3/5.9_0.8%, CuO/2.35_0.2%. They can be identified as green glasses whose chromophores are copper ion (Cu^{2+}). Their use in the fibulae suggests their dating to the late 5th century or early 6th century: this is calcium sodium glass, with a composition similar to Levantine glass, in which the melting agent is natron. This glass composition, however, shows some peculiarities that place it in the type called HIMT (high iron, manganese and titanium), originating in the sand beaches of Egypt, and which was widely used in the Mediterranean, essentially in the regions of the north-west of the Roman Empire, between the 4th and 5th centuries.[53]

Regarding the composition of the garnets, it is possible to identify three distinct groups. If we take a look at Figure 5 on the multivariate classification of the chemical components, we can see that the garnets of the bird-shaped fibulae are of the same type and can be assimilated to group II in the classification made by Calligaro, coming from India.[54]

The homogeneity of the fibulae in terms of the gold alloy and glass composition is further outlined by the flat-cut garnet inlays. Despite a very similar composition, some little differences, such as a slight increase in silicon concentration, can be observed in the composition of the leaf-shaped pendant (NC5), although they do not change the class to which these gemstones belong.

That suggests that the flat-cut garnets, used on both fibulae and on the pendant, may belong to a single source; and, probably, as the gold alloys also seem to suggest, they were assembled together in a single production centre operating in the late decades of the 5th century or the beginning of the 6th.

As for the two-part garnet pendants, the series of measurements without the collimator shows that three of the four gemstones examined show significantly lower percentages of MnO than the flat-cut garnets, and also the presence of anatase (TiO_2). As for the fourth garnet (NC10), it shows a composition similar to the previous ones, although the chemical classification places it in a separate position (Fig. 5).

The presence of low concentrations of titanium, associated with the absence of chromium compounds, suggests a European origin for garnets NC4, NC6 and NC11, probably related to Mount Suímo (Portugal), which corresponds to group IV of the Calligaro classification.

As mentioned, a difference can be observed between the gold alloys used in these two-part pendants and the objects decorated with flat-cut inlays (fibulae and leaf-shaped pendant). It can therefore be hypothesized that the two groups of objects were originally manufactured in two distinct production environments having access to different raw materials. These dissimilarities could mirror either geographical or chronological differences, or both. The wide geographical dissemination of the two-part pendants with round and oval garnets, as well as their imprecise dating, leaves the issue unresolved.

Another prominent example of 5th – 6th century gold jewellery is the treasure found near Desana in the Vercelli province (Italy). The assemblage was analysed in 2022 by the MAIN group using pXRF and FORS, as part of the same research project as the contents of the present paper.[55] Although the dataset processed within our project is still too small to draw definitive conclusions, comparing the results from Desana with those of the Potoci pectoral appears as a good way to address the issue of the production centres of 5th – 6th-century gold jewellery and to sketch some preliminary observations.

52 Fiocchi Nicolai 2013, 65–66. The composition of the golden alloy of the cabochon holding the garnet has been published, but not the composition of the barrel-shaped beads (Ferro *et al.* 2017, 38).

53 Foy *et al.* 2003; Nenna 2014; Freestone *et al.* 2018.

54 Pion *et al.* 2020.

55 Aceto *et al.* 2023.

56 Aceto *et al.* 2023, 1690–1693; Pinar Gil *et al.* 2023, 76–77.

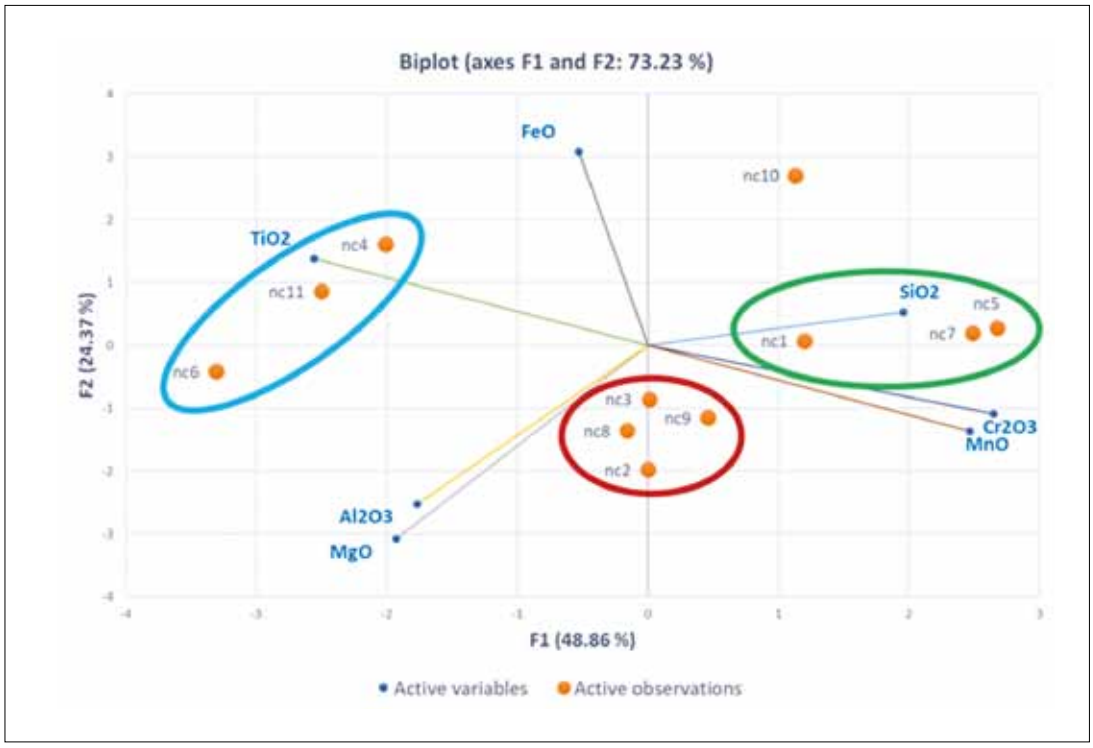

FIGURE 5. Distribution of the garnets in the pectoral according to the different composition in oxides (made by A. Agostino).

Potoci and Desana share two interesting features: the presence of different qualities of gold and of gemstones of different provenances, as well as evidence of recycling/remounting of jewellery (the pectoral from Potoci itself, and an earring with drop-shaped pendant at Desana). These should be regarded as two recurring characteristics of Odoacrian/Ostrogothic-period jewellery, as they seem to be present in other significant deposits of that time, such as Reggio Emilia, Imola-Villa Clelia, Landriano and Kranj-Lajh.

The alloys used in jewellery of the late 5th and early 6th centuries are rather similar in both assemblages (Fig. 7): the so-called 'jewellery set 1' from Desana shows an average composition consisting of Au/83.8_1.3%, Ag/12.4_1.3%, Cu/3.8_0.8%, which appears comparable to the Potoci two-part garnet pendants and beads. 'Jewellery set 2' from Desana, instead, appears to be close to the Potoci fibulae, chain and leaf-shaped pendant (Desana 2: Au/92.2%, Ag/5.8%, Cu/2.0%; Potoci: Au/94_2%, Ag/4.25_1.75%, Cu/1.5_0.5%).[56]

An important difference, however, lies in the functionality of the items belonging to each grouping. In Desana, the fibulae and necklaces belong to a 'lower-quality' grouping, whereas in Potoci the fibulae, chain and central pendant are made of significantly purer gold.

The presence of garnets of both Indian and Portuguese origin is a relevant similarity between the Desana treasure and the Potoci pectoral. The only Portuguese garnet identified in Desana has been preliminarily interpreted as an old item at the time of the production of the necklace in which it had been inlaid,[57] a hypothesis that may be supported by the attribution of the Potoci garnets to the group of older jewels in the pectoral. The presence of morphologically similar garnets (middle- and large-sized, oval-shaped) from Monte Suímo in the broadly coeval deposits of Desana and Potoci, however, raises the question about the actual extraction and distribution of Portuguese garnets in the 5th – 6th-century Mediterranean – a question that is also alluded to by recent identifications of Portuguese garnets in the Carpathian basin and eastern Africa.[58]

The differences in the 'Roman-Germanic' jewellery sets (pairs of cloisonné fibulae and necklaces with garnet inlays) of both deposits are, however, remarkable. As a working hypothesis, it may be suggested that they were produced in different workshops operating broadly at the same time. For Desana, attribution to a Ravenna workshop has been hypothesized, on the basis of the geographical distribution of some of the artefacts of Desana's 'jewellery set 1'.[59] A similar attempt built on the basis of selected finds from Potoci shows a different picture, as the closest parallels display much tighter relations to South-Eastern and Central Europe than the Desana objects: thus, the bird-shaped fibulae and the leaf-shaped pendant display stylistic affinities with the Danubian lands and Southern Germany, whereas the two-part pendants show affinities with the eastern Balkans and the Black Sea region.

57 Aceto *et al.* 2023, 1693–1694.

58 Bugoi, Oanță-Marghitu, Calligaro 2016; Horváth *et al.* 2024; Then-Obłuska *et al.* 2021.

59 Pinar Gil *et al.* 2023, 80.

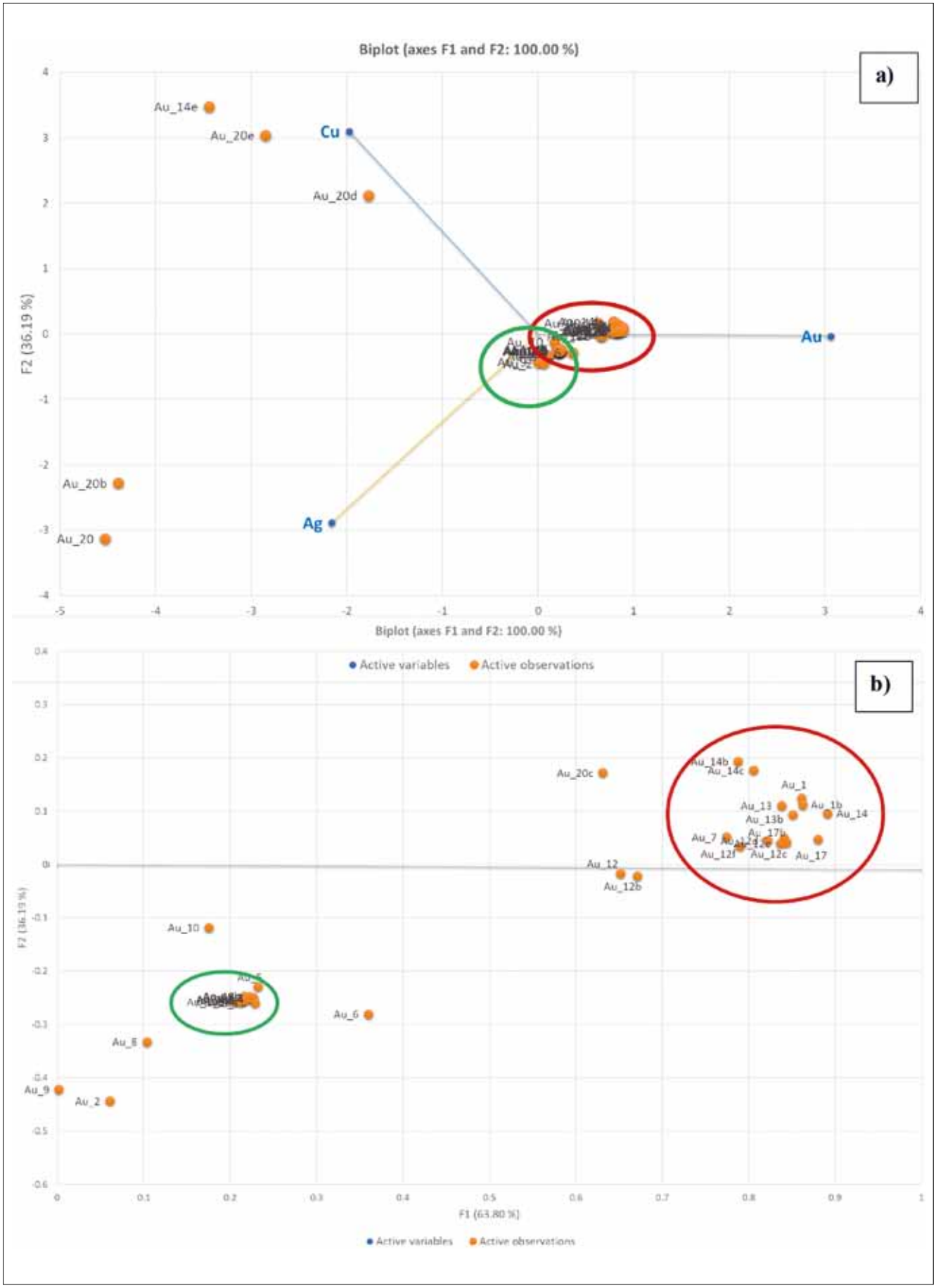

FIGURE 6. Distribution of the gold alloys in the pectoral according to the different elemental composition (made by A. Agostino).

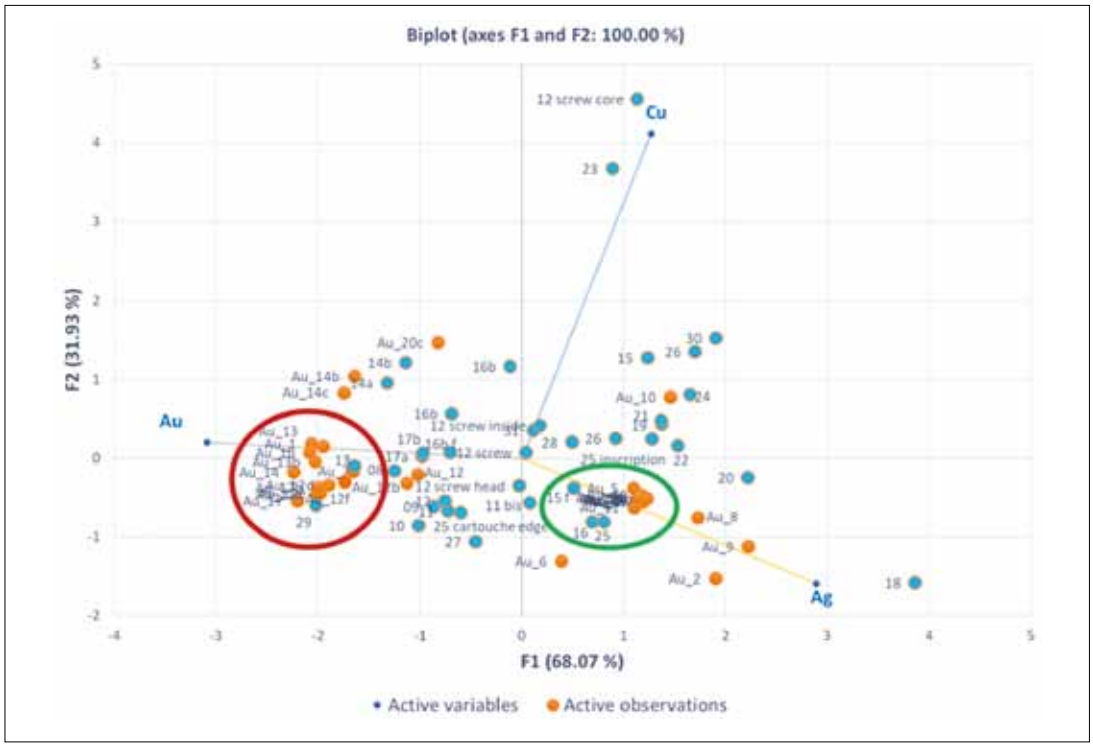

FIGURE 7. Principal-Components Analysis (PCA) of the gold alloys of the pectoral from Potoci (orange) in comparison with the data of the 'treasure of Desana' (turquoise). Red grouping: Desana 'jewellery set 2' and Potoci 'newer' components. Green grouping: Desana 'jewellery set 1' and Potoci 'older' components (made by A. Agostino).

As said, the find spot of the pectoral cannot conclusively be proven. The results of the re-examination outline a still unknown production centre being connected with Danubian, Italian and Pontic influences, and having access (either directly or indirectly) to trade networks distributing Eastern Mediterranean glass and both Portuguese and Indian garnets throughout the Mediterranean. A goldsmith workshop operating somewhere in the eastern Adriatic or in the Balkans seems thus a convincing possibility. A further argument to be added to the discussion on the provenance of the pectoral is that the main 'signature features' of the production centre of the pectoral seem to be echoed by the finds from the second sarcophagus in Potoci: combination of 'old' and 'new' components, contacts with Central Europe, Italy and the Black Sea region, use/deposition around 500 AD or slightly later. This hypothesis, however, should be tested with further archaeometric analysis.

SAŽETAK

NEINVAZIVNA ANALIZA ZLATNOG PEKTORALA S PAROM FIBULA U OBLIKU PTICA I PRIVJESCIMA IZ ZBIRKE ARHEOLOŠKOG MUZEJA U ZAGREBU

Zlatni pektoral s almandinima sastavljen od lančića s dvije fibule u obliku ptica grabljivica na krajevima i pet privjesaka koji vise između njih u relativno pravilnim razmacima, otkupljen je 1933. godine za Arheološki muzej u Zagrebu, a uvriježena je pretpostavka da potječe iz mjesta Potoci nedaleko Mostara u Bosni i Hercegovini.

U okviru interdisciplinarnog projekta Sveučilišta Kraljičin Gradac (češki Hradec Králové) kojemu je jedan od ciljeva utvrditi kemijski sastav zlatnog nakita pronađenog na području Ostrogotskog Kraljevstva, na pektoralu je 2022. godine provedena rendgenska fluorescentna spektroskopija (XRF). Rezultati su pokazali, a time i potvrdili ranije iznijeto opažanje, da je riječ o komadu nakita sastavljenom od različitih komponenata – novih, posebno izrađenih (fibule, lančići i središnji listoliki privjesak) koji se datiraju u kraj 5. i prva desetljeća 6. stoljeća te onih starijih (dvodijelni privjesci i pripadajuće bačvaste perle), vjerojatno recikliranih od nekih drugih ogrlica ili narukvica, čiji se vrhunac proizvodnje datira gotovo stotinu godina ranije. Proizvodni centar, hipotetski smješten na istočnom Jadranu ili na zapadnom Balkanu, raspolagao je zlatnim legurama različitih kvaliteta, almandinima s područja Indije i Portugala te staklom s visokim udjelom željeza, mangana i titana (HIMT staklo) istočnomediteranskog porijekla.

Rezultati provedenih analiza ne mogu potvrditi, ali ni demantirati atribuciju pektorala kao jednog od nalaza iz prvog sarkofaga pronađenog 1882. godine u Potocima. Njegove glavne proizvodne značajke prisutne su i na nalazima iz drugog sarkofaga pronađenog 1890. godine, što uključuje kombinaciju starih i novih komponenti, kontakte sa srednjom Europom, Italijom i crnomorskom regijom, te njihovu upotrebu oko 500. godine ili nešto kasnije.

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