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Triangle from the Past: A Late Ottoman measuring instrument

Aleksandar Jašarević
Doboj

Abstract: In this study, we present an unusual instrument that is rarely seen in museum collections. This richly decorated brass triangle belongs to a group of objects used by Ottoman architects and engineers. The level or *havāyī terāzū* is an instrument that has a wide application in geometry, architecture, military engineering, hydraulic works, and topography. With its rich decoration, it can certainly be seen as a work of applied art and an artifact that – alongside its functional role – also has a symbolic value. Dating of the level is possible based on comparisons with other finds, especially those from the collections of the Pera Museum in Istanbul and the Petrovic Collection at the Canada Science and Technology Museum in Ottawa. However, the level from the Museum in Doboj is significant because it was cast in a form that is unique among levels known to date. Detailed descriptions of the instrument can be found in medieval Persian and Arabic treatises, later Ottoman studies, and Renaissance European publications. Finally, this study provides an opportunity for the wider public to learn about a lesser-known artifact, and to encourage the publication of similarly little-known ones.

Key words: Ottoman period, level, geometry, architecture, measuring instrument

Introduction

Museums often have tens of thousands of items in their collections, so it comes as little surprise that things occasionally get misidentified, misplaced, or even lost; but it is a nice surprise to rediscover them in a museum's depot. Preparing a permanent archaeological exhibition for the Museum in Doboj in 2021, we came across a very interesting artifact. In the museum's inventory book, the item numbered 4,779 is marked as medieval or Ottoman-period level. It was acquired in 1973 from Velika Sočanica, near Derventa. The artifact is shaped as an equilateral triangle, measuring 8.5 cm in length, 6.7 cm in width, and 0.3 cm in depth, and cast in brass. It is smaller than many levels, with elaborate decorative features, some of which indicate that it may well have belonged to an architect rather than to a builder, and likewise that it may have functioned as a ceremonial – rather than practical – implement. The tips that were used for suspending the instrument on a string have been broken off. On the central part, a hole for threading the plumb line and an incised line in the direction of extension have been preserved. Below the upper right area are traces of repairs with a preserved iron pin.

Known from Spain to Iran, under the names *murjiqāl* (from the Spanish *murciélago*, for the animal 'bat') or *mizān* ('balance' in Arabic), in Turkish-speaking Ottoman regions it was known as *havāyī terāzū* ('aerial balance').[1] From the Turkish *havāyī terāzū* comes the Slavic version *terezije*; alternatively, it is known as a *radilo*.[2] The level is described in a book on planar Euclidean geometry, preserved in Arabic transcription, as *al-kūniyā al-hawā'iya*. Probably of Greek origin (*kuniyā* is derived from γωνία, meaning 'angle'), it was a common instrument in the medieval Islamic world.[3] Basically, the *havāyī terāzū* is an instrument that has a wide application in geometry, architecture, military engineering, hydraulic works and topography.[4] It is used in a simple but effective way: Each end of the *havāyī terāzū* was attached to a cord, with this cord being stretched

[1] Abdeljaouad / Ageron 2020, 24; Umut / Pantalony 2020, 201; Karakaş 2021, 323.
[2] Цветковић 2005, 598.
[3] Abdeljaouad / Ageron 2020, 23.
[4] Aslan Seyhan 2019, 247; Kale 2020, 138; Abdeljaouad / Ageron 2020, 24; Karakaş 2021, 323.

taut between the two poles. The person holding the first pole placed it in position, and the other person lowered or raised the other end of the cord until the plumb line was positioned in such a way that the plumb bob (*ṣākūl*) stopped oscillating, indicating that the cord was a straight horizontal line, marking the two points as level. The person carrying the first pole noted the place indicated on the pole by the cord to measure any difference in height, and then moved in the chosen direction to continue the leveling. Thus, builders were able to measure a slope with a value.[5]

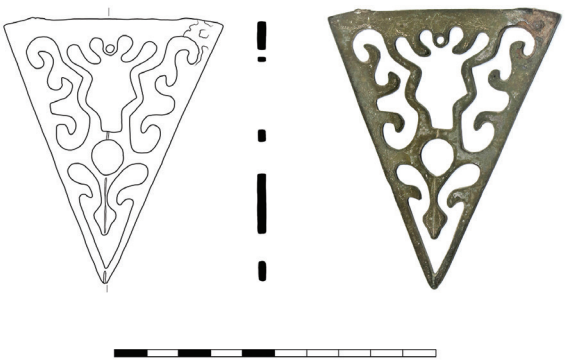

Figure 1. *Level from Museum in Doboj (photo A. Jašarević)*

The first description of an example of this type of level was given by the famous Serbian architect Milan Zloković. Using his professional knowledge of geometry, he gave the first interpretation of the level based on two instruments; a very decorative one from Belgrade and another of simple form from Kruševo in Macedonia. Although his interpretation was more focused on technical properties, he determined that both specimens dated to the Ottoman period.[6] An Ottoman provenance is further confirmed by the fact that such specimens are exclusively recorded in the Balkans and the western parts of Asia Minor. The two largest collections are those from the Pera Museum in Istanbul, which hosts a collection of aerial balances dated to between the 16th and 19th centuries, and the endowment of George Petrovic (Đorđe Petrović), held by the Canada Science and Technology Museum in Ottawa.[7] The Petrovic Collection consists of 130 artifacts including rulers, compasses, levels, plumb bobs, and other kinds of measuring instruments. His collections mainly come from the territory of the Balkans and the Eastern Mediterranean region, mostly produced or used in the Ottoman territories.[8] Among the Ottoman instruments in the Petrovic Collection are fourteen levels, dated by Petrovic to between the 15th and 18th centuries. Some of them are plain, while others are elegantly shaped and decorated in a variety of ways.[9]

A concise and detailed synthesis of levels from the territory of Serbia was given by B. Cvetković in 2005. He described all known finds and provided basic guidelines for dating, while also demonstrating the contexts in which they were used.[10] The main issue was dating, as none of the known artifacts have been found in an archaeological or historical context, meaning that the only bases for determining their age have been stylistic-typological characteristics and comparisons between examples from different museum collections. A level described by Cvetković from Ostrikovac near Ćuprija, held in the collections of the Regional Museum of Jagodina, is dated to the late Middle Ages, although the author remained open to a different dating.[11] Dating to a later period is an extremely important level from Brezna, Gornji Milanovac, which has been preserved in its original box with an accompanying plumb. Among other things, a very valuable piece of information about this level has been preserved; it was used in the construction of the church of St. Dimitrija in the village Brezna in 1837, where it was found.[12] Exclusively based on their features and materials, other levels from Prekonoga near Svrljig,[13] Knjaževac[14] and Sumrakovac near Zaječar[15] are mistakenly dated to the Roman period. Somewhat different dating is presented for a level from the site of Klance, near Surdulica, held in the collections of the National Museum in Belgrade. According to the style of floral ornamentation, in which elements of late Baroque

[5] Umut / Pantalony 2020, 202; Karakaş 2021, 323-324.
[6] Zloković 1957, 298; Цветковић 2005, 598.
[7] Kürkman 2003, 90; Umut / Pantalony 2020, 187.
[8] Umut / Pantalony 2020, 187-188.
[9] Ibid. 201. The dating of this to the 15th century is questionable, as recent metallographic analysis has shown.
[10] Цветковић 2005, 603-604.
[11] Ibid. 606; Трајков 2021, 100, kat. 90.
[12] Цветковић 2005, 604.
[13] Петровић / Филиповић / Миливојевић 2012, 205. kat 143.
[14] Петровић / Јовановић 1997.
[15] Popović / Mano-Zisi / Veličković / Jeličić 1969, 157. kat. 340.

can be discerned, this is classified as an object of artistic design dating to the 17th or 18th century.[16]

Historical descriptions

The level is an instrument that was already known to the Ancient Egyptians and Romans, They used various tools incorporating lines and weights, i.e. plumb lines and bobs.[17] Representations on ancient monuments and archeological finds suggest that they predominantly existed in a simple form known as an A-shaped level.[18] However, detailed descriptions of the use of such instruments can be found for the first time in medieval Persian and Arabic texts. In the treatise *Kitab al-Hawi*, written in Iraq in the 11th century by an unidentified author, there are instructions for the manufacture and use of three leveling instruments. The second described instrument consists of an equilateral triangle made of metal, with two hooks soldered to either end of its hypotenuse. A narrow hole is drilled through this side, to take the cord of a plumb line.[19] In the same century, the Persian mathematician al-Karaji (d. 1029) in his book *Inbāt al-miyāh al-khafiyah* (Book on Extracting Hidden Waters) gave detailed instructions for measuring heights and distances with different types of balances on-site, along with geometrical proofs for the design of instruments he made. The instrument described consisted of a triangular plate, a plumb bob, and a cord of 30 cubits divided by knots, which were used together with two measuring rods. Al-Karaji explained its manufacture and use, and his drawing of it resembles the 18th- and 19th-century balances preserved in museum collections.[20] Another clear description of such a level can be found in the works of two well-known authors of the 13th century; Abū al-Ḥasan al-Marrākushi and Quṭb al-dīn al-Shirāzī.[21]

The most prolific description and illustration was given, however, by the Andalusian scholar Ibn Luyūn. He is mentioned in biographical sources as an ascetic, philosopher, jurist, mathematician and amateur poet. He was born in Almería in 1282, also dying there in 1349, during the Black Death pandemic, and was the author of nearly one hundred works. He composed his *Kitāb ibdāʾ al-malāḥa wa-inhāʾ al-rajāḥa fī uṣūl ṣināʿat al-filāḥa* ('Book on the principles of beauty and the purpose of learning, concerning the fundamentals of the art of agriculture'), also known simply as *Kitāb al-filāha* (Treatise of Agriculture), in 1348, making it the last known Andalusī agricultural work. This book covers a wide range of agricultural and horticultural themes.[22] For us, perhaps the most important visual representation is that of the instruments that were used in the construction of irrigation systems. One such instrument is named a *murjiqāl*. Leveling with the *murjiqāl* is done using two sticks set upright on the ground, with their tips joined by a piece of string and a string joins the tip of one stick with the tip of the other, with the *murjiqāl* being suspended in the middle of the string. The *murjiqāl* itself consists of a triangle made of wood, in the middle of which a line is drawn; furthermore a thread is suspended from it, to the end of which a weight (the lead plumb) is attached.[23]

The Ottomans also followed the Islamic tradition with regard to the creation of instruments. In this period, mathematics and astronomy were of particular importance in solving key problems about a number of everyday issues, including accurately calculating prayer times, finding the direction of the qibla (the direction of Mecca), navigation on the sea and land, and for architecture and ornamentation.[24] Therefore, instruments that aided in solving these problems were held in high regard. Their study began with the establishment of the first madrasas in the 14th century and lasted until the mid-18th century, with mathematical mathematical and astronomical works documenting their use first being systematically reproduced in Constantinople at the personal request of Sultan Mehmed II (1432–1481).[25] In the later period however, the core interest stemmed from military needs. The level instrument is described by Osman Efendi (1713–1774) in his book *Hadiyyat al-Muhtadī* ('The Gift of the

[16] Томић 2007, 74.
[17] Shelby 1961, 127.
[18] Glick 1968, 169; Belhout 2019, 155.
[19] Hill 1996, 117.
[20] Kale 2020, 137.
[21] Sezgin 2010, 142; Abdeljaouad / Ageron 2020, 23.
[22] Fairchild Ruggles 2000, 25-26.
[23] Sezgin 2010, 140.
[24] Aslan Seyhan 2019, 245; 2019a, 39.
[25] Aslan Seyhan 2019, 245.

Figure 2. *Ilustration of murjiqāl from Ibn Luyūn Kitāb al-filāha (The Filāḥa Texts Project)*

Convert') from 1779. Osman Efendi's mathematical treatise is the only book he wrote in Arabic. *Hadiyyat al-Muhtadī* is actually an elaborate personal work, going far beyond a simple translation of pre-existing works: While initially the work appears to predominantly be a careful blending of chapters of several European books, freely translated with additional commentary, Efendi also incorporated a wide range of non-European features into the book, seemingly largely taken directly from Islamic knowledge of the living tradition. Osman's treatise is arranged in two parts, each divided into three books. Descriptions of instruments are to be found in five of these six books. In many cases, but by no means ubiquitously, they are accompanied by neat drawings.[26]

A summary of the most widely circulated late mathematical sources in which this instrument is discussed cannot be considered complete without mentioning the textbooks by Bahāʾ aldīn al-ʿĀmilī (d. 1621) called *Khulāṣat al-ḥisāb* (The Very Essence of Arithmetic) and ʿAbd al-laṭīf b. Aḥmad al-Dimashqī (d. 1749) titled *Sharḥ Nukhbat altuffāḥa fī ʿilm al-misāḥa* (Commentary on the Best of the Apple in the Science of Measurement).[27] Both were still commonly used in the 19th century, as can be seen from the very precise account by the French traveller Antoine François Andréossy of the methods employed by Constantinople's fountain-makers.[28]

A similar device was described and depicted in Al-ʿAmilī's (d. 1622) renowned 17th-century book *Khulāṣat al-ḥisāb* (The Essentials of Arithmetic) and its late 18th-century commentary.[29] Architects used similar levels to lay out foundations. In his account of the 1609 foundation-laying ceremonies of the Sultan Ahmed Mosque in Istanbul, Ahmed I's spiritual adviser, Mustafa Safi, praises architect Mehmed Agha as an expert in geometry and describes him using an instrument called "an aerial balance". In *Risāle-i miʿmāriyye*, an early 17th-century Ottoman treatise on architecture, the entry for the balance, called *terāzū*, is listed together with tools used for measuring, laying out, and leveling foundations and buildings. Sources demonstrate that the balance – called "aerial" because it was suspended between two poles – was a surveying

[26] Abdeljaouad / Ageron 2020, 17-19.

[27] Ibid. 24.

[28] Andréossy 1828; Abdeljaouad / Ageron 2020, 24.

[29] Abdeljaouad / Ageron 2020, 24.

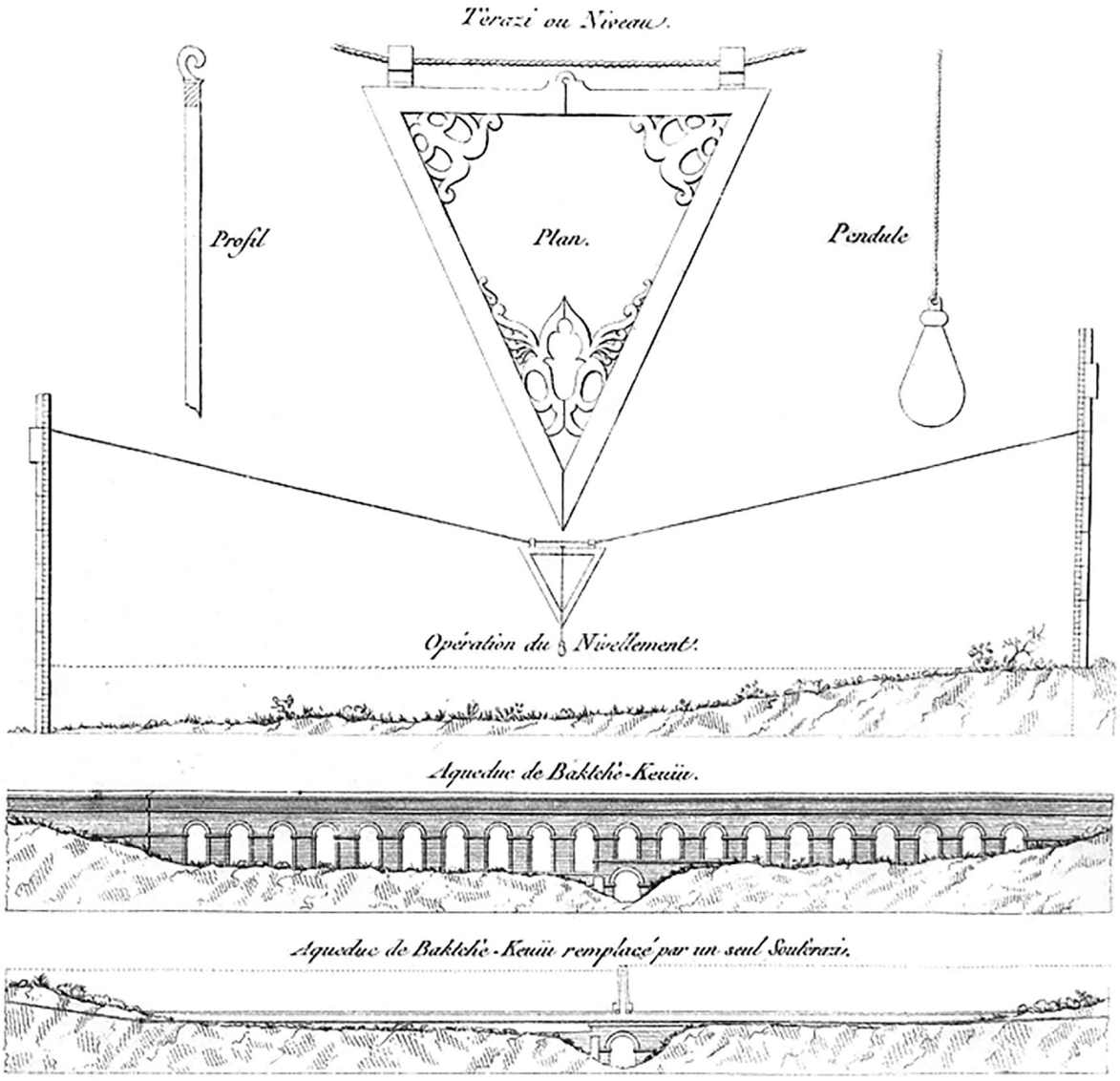

Figure 3. *Illustration of 19th century aqueduct from Constantinople* (Andréossy 1828)

device used by Ottoman architect-engineers for measuring distances, heights, and depths, and for leveling and partitioning surfaces. Moreover, the similarities between historical instruments held in museum collections and the illustrations in widely read mathematical books indicate that scholars knew the importance of these tools for practical operations.[30]

The level was also used in military engineering, as famously described by Ottoman scholar Ishak Efendi in his work *Mecmua-i Ulûm-ı Riyâziye*, published between 1831 and 1834.[31] Since the Ottomans were a militarily-oriented society, once they realized fact that they fell behind of the technology of their Western rivals in the battlefield, they made a number of urgent military reforms. In order to train elite cadets and integrate Western knowledge into the empire's military, they established the Imperial Naval Engineering School and Imperial School of Military Engineering. However a comprehensive functioning of the curriculum was only made possible by means of educational reforms in the second half of the 19th century, due to the conservativism of many teachers, who were ardent supporters of the madrassa educational system, with these engineering schools standing at the center of conflicts between traditionalists

[30] Kale 2020, 138.
[31] Dosay Gökdoğan 2019, 5-8.

and secularists.[32] From this period, lists of instruments used in the Ottoman military engineering academies have been preserved (inventory lists of tools and instruments dating to the years 1801, 1816, 1822, 1826 and 1836), although no pictures or explanations are contained in these documents. Original versions of these instruments are not exhibited anywhere as a complete set or inventory, and therefore we are only able to refer to reference books and museum catalogs to make reasonable inferences as to their identification. One such instrument mentioned is a *Hedefeli ve ruhlu demir kollu tesviye terazisi*, which can be described as a leveling instrument with a target and moveable iron handle.[33]

It is interesting that this form of air-balance level is not presented in European medieval depictions.[34] This changes during the 16th century.[35] The treatise by Olbrycht Strumieński *O Spráwie Sypániu, Wymierzániu, y Rybieniu stawów*... (On making, coffering, surveying, and stocking ponds with fry…) from 1573 was the first book in Poland, and the second in Europe, to describe leveling instruments. This was preceded by Jani Dubravii's *De piscinis* from 1547, and its Polish version *O rybnikach y rybach* (About Fishponds and Fish). Unlike Dubravii, Strumieński provided a great deal of practical and technical information about carrying out field work, such as finding the right site, the measuring procedure, and undertaking earthworks.[36] The treatise must have been popular, considering the fact that after the death of Strumieński, Jan Januszowski (?-1588) published a reprint in 1605. Just four years after the second release of Strumieński's treatise, the text was re-published in Krakow by Stanisław Stroynowski (1580–?) in his 1609 work *Opisanie Porządku Stawowego y przestróg niektórych domowego gospodarstwa* (Fish Pond Management). These were the only three Polish-language treatises addressing the problems of leveling written prior to the 19th century. Stroynowski preserved the text by Strumieński, but added more information on aquaculture and fish species. Strumieński's book has an extremely practical value; it is written in simple, clear language, and contains many technical notes that reflect the author's own experiences, as well as a detailed description of the instruments, and leveling and hydraulic engineering works. Strumieński focused on three instruments: the synbalance, archipendulum (rope-level) and water level. The example from our collection can be attributed to the type classified as an archipendulum; a level balance consisting of a metal triangular plate. The plumb bob was suspended centrally along the side, on the string, to cover the check hole near the bottom apex of the triangle when level.[37] It is not known what the sources were for the compilation of Polish treatises in the 16th century, but it is most likely that they were medieval Andalusian works, which reached Central and Eastern Europe via the Jewish community after its exodus from Spain.

Figure 4. *16th century surveying instruments box* (Museo Galileo, Florence)

[32] Aslan Seyhan 2019, 257.

[33] Ibid. 257, 247.

[34] Turner 1998; Engraved examples of an air-balance level from the monastic complexes of Manasija and Dečani (Ненадовић 2002, 123; 2003, 51-53; Цветковић 2005, 599) most likely belong to architectural or artistic interventions from the latter period, i.e. the 17th or 18th century.

[35] In Europe, it is also called the 'mining triangle', which was used until the 19th century to determine the slope of a quarry (Kürkman 2003). This is documented by 16th-century surveying instruments box from the Museo Galileo in Florence. A typical set of mining instruments was brought to Florence from Germany by Prince Mattias de' Medici in the first half of the 17th century (https://catalogue.museogalileo.it/object/BoxMiningInstruments.html).

[36] Taborska 2019, 30.

[37] Ibid. 31-33.

Conclusion

Museums hold large collections of objects of different materials and from different periods, and not all of these can find their place in permanent exhibitions. However, some objects attract the special attention of researchers due to their appearance, material, and way of use. We presented one of these artifacts in this study; a late Ottoman measuring instrument known as *havāyī terāzū*, or air balance level. We are convinced that the number of such items is far greater, and that museums have among their collections similar highly unusual items that have often been placed in different archaeological, historical and ethnological collections, but it is important to recognize and present their existence. Artifacts like this have the potential to reveal some of the complexities of the mathematical, architectural, and trading cultures in the pre-modern and early modern world, as well as the ways in which we have collected this material history and constructed narratives around the collections in which they are held. Here, ample evidence is provided to suggest that Ottoman architects used this kind of instrument to measure distances, heights, and depths, as well as for leveling and partitioning surfaces.

Dating is possible based on comparisons with other finds, especially those from the collections of the Pera museum in Istanbul and the Petrovic Collection in Otawa. However, the level held in the collections of the Museum in Doboj is significant because it was cast in a form that is unique among examples known to date. Its level of decorativeness seems to have played a significant role in its design, and is uncommon among purely utilitarian examples, implying that this specific example was not purely functional in nature, but also had the role of a symbolic and prestigious object for the architect(s) who used it. That it was an object of special importance through several generations is evidenced by the care taken of it, i.e. visible repairs, suggesting that this instrument was connected to its owner(s) in a special way. Instruments often create a specific narrative that is closely related to a person or community, which we are able to recognize as such in archaeological and historical contexts. This is well illustrated for example, in the custom in Serbia of depicting craft symbols or other symbolic identifiers of an individual's social role on grave markers, which was maintained for centuries until the most recent times, up to and throughout the 19th and 20th centuries.[38]

The Ottoman provenance of the item is also confirmed by the materials used for its production; brass was mainly used in the production of later examples, often those from the 18th century. Also, it is an artifact that distinguished the guild of architects in the wider Ottoman area, so questions remain as to the actual place of production. Certainly, it could be a product of the skilled artisans from the widely known workshops of Sarajevo, Skopje, Pristina or the Imperial capital of Constantinople itself. The fame of Ottoman metalwork reached its zenith during the 18th century, as is attested to by surviving pieces made by Ottoman artisans, who not only made use of the empire's metalworking heritage and traditions in the best way possible to produce striking examples demonstrative of the Ottomans' sophisticated taste, elegance and imagination,[39] but also drew from Western influence, which affected all branches of art, including metalwork, at this time.[40] Some of the levels clearly indicate the influence of the European late Baroque. Finally, we can certainly see such an artifact as a small masterpiece of applied art worthy of our attention and deserving of being published in detail. It is a reflection of the extraordinary craftsmanship and refined taste of late Ottoman metalwork.

Rezime

Trougao iz prošlosti: Kasnoosmanski mjerni instrument

U ovoj studiji predstavljen je neobičan instrument koji se rijetko viđa u muzejskim zbirkama. Bogato ukrašen mesingani trougao pripada predmetima osmanske provenijencije koje su koristili arhitekti i inženjeri. Radilo ili *havāyī terāzū* je instrument koji ima široku primjenu u geometriji, arhitekturi, vojnom inženjerstvu, hidrauličkim radovima i topografiji. Svojom osobenom dekoracijom svakako se može posmatrati i kao djelo iz oblasti primijenjene umjetnosti,

[38] Дудић 1995; Цветковић 2005, 602.
[39] Bilgi / Eruz 2004, 198-199.
[40] Ibid. 209; Karamehmedović 1980.

artefakt koji je, pored funkcionalne uloge, imao i onu simboličku, odnosno ceremonijalnu. Detaljni opisi instrumenata i načina na koji su korišteni mogu se naći u srednjovjekovnim perzijskim i arapskim traktatima, kasnijim osmanskim, odnosno renesansnim evropskim studijama. Datiranje predmeta moguće je na osnovu poređenja s drugim poznatim primjercima, prvenstveno onima iz zbirke Pera muzeja u Istanbulu i zbirke Đorđa Petrovića iz Nacionalnog muzeja nauke i tehnologije u Otavi. Međutim, radilo iz Muzeja u Doboju je značajno jer je izrađeno u formi koju ne ponavlja nijedan drugi poznati primjerak. U muzejskoj inventarnoj knjizi pod brojem 4779 označeno je kao predmet iz srednjeg vijeka ili osmanskog perioda. Otkupljeno je 1973. godine iz Velike Sočanice kod Derventе. Artefakt je u obliku jednakokrakog trougla; dužine 8,5 cm, širine 6,7 cm i debljine 0,3 cm. Izrađen je tehnikom lijevanja i prolamanja s razrađenim apstraktim dekorativnim motivima. Vrhovi koji su služili za kačenje instrumenta o uzicu su odlomljeni. Na središnjem dijelu, s unutrašnje strane, očuvana je rupa koja je služila za suspendiranje viska, kao i simetrična urezana linija u smjeru produžetka viska. U desnom gornjem uglu nalaze se tragovi kasnije popravke s očuvanim željeznim klinčićem. Ovo ide u prilog višegeneracijskoj upotrebi i važnosti predmeta, koji se dugo čuvao kao dio tradicijske vrijednosti. Prvi opisani primjer ovog tipa dao je poznati srpski arhitekta Milan Zloković. Koristeći svoje stručno znanje iz geometrije, dao je prvu interpretaciju radila na osnovu dva instrumenta, jednog vrlo dekorativnog iz Beograda i drugog jednostavne forme iz Kruševa u Makedoniji. Iako je tumačenje bilo više usmjereno na tehničke karakteristike, odredio je njegovo datiranje u osmansko razdoblje. Identično porijeklo donekle potvrđuje činjenica da su primjerci do sada isključivo zabilježeni na centralnom Balkanu i u zapadnim dijelovima Male Azije. Konciznu i detaljnu sintezu radila s teritorije Srbije dao je B. Cvetković 2005. godine. On je opisao sve poznate nalaze i dao osnovne smjernice za datiranje i kontekst u kome su korišćeni. Datiranje je otežano i činjenicom da nijedan od poznatih artefakata nije pronađen u arheološkom ili istorijskom kontekstu. Dakle, jedina osnova za datiranje bile su stilsko-tipološke karakteristike i poređenje s drugim poznatim artefaktima iz različitih muzejskih zbirki. U tom kontekstu najveći broj radila može se datirati u period 17. i 18. vijeka, i to na osnovu stila umjetničkog oblikovanja u kome se kod pojedinih primjeraka naziru elementi evropskog kasnog baroka, odnosno materijala od kojih su izrađeni. Mesing je legura koja se u osmanskoj produkciji češće koristi od 17. vijeka. Nadalje, oni su odraz izvanredne izrade i istančanog ukusa kasnoosmanske metalne produkcije. Sigurni smo da studija pruža priliku da se prikažu manje poznati, ali značajni artefakti i da se podstakne objavljivanje sličnih.

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