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ANCIENT AND MEDIEVAL NUMISMATICS IN THE CONTEXT OF CONTEMPORARY METHODOLOGICAL PARADIGMS

VALERII KAPELIUSHNYI
MYKHAILO ORLYK

ABSTRACT

The paper systematizes the potential of archaeometry, X-ray fluorescence analysis, statistics of physical wear, and die modelling as instruments for reconstructing the geography of metal, the scale of coin emissions, and the dynamics of monetary circulation. Particular attention is given to the role of the “material turn” and the concept of the “biography of things,” which interpret the coin as a physical object possessing a technological history and variable social functions. The article also highlights the potential of Linked Open Data (Nomisma.org, OCRE) and databases for the topography of coin finds (CHRE, DARMC, FLAME), as well as the application of artificial intelligence and computer vision for the automation of die analysis. The conclusions emphasize that numismatics is evolving from a descriptive corpus-based discipline toward an interdisciplinary analytical-network model in which the coin appears as a material, digital, and symbolic source for historical and economic reconstruction.

REZUMAT: NUMISMATICA ANTICĂ ȘI MEDIEVALĂ ÎN CONTEXTUL PARADIGMELOR METODOLOGICE CONTEMPORANE

Articolul sistematizează potențialul arheometriei, al analizei prin fluorescență X, al statisticilor uzurii fizice și al modelării ștanțelor ca instrumente pentru reconstrucția geografiei metalului, a amplitudinii emisiunilor monetare și a dinamicii circulației monetare. O atenție deosebită este acordată rolului unor concepte ca „material turn” și conceptului de „biografie a lucrurilor”, care interpretează moneda ca obiect fizic ce posedă o istorie tehnologică și funcții sociale variabile. Articolul evidențiază, de asemenea, potențialul Linked Open Data (Nomisma.org, OCRE) și al bazelor de date pentru topografia descoperirilor monetare (CHRE, DARMC, FLAME), precum și aplicarea inteligenței artificiale și a viziunii computerizate pentru automatizarea analizei ștanțelor. Concluziile subliniază faptul că numismatica evoluează de la o disciplină descriptivă bazată pe corpus spre un model interdisciplinar de analiză relațională, în care moneda apare ca sursă materială, digitală și simbolică pentru reconstrucția istorică și economică.

KEYWORDS: numismatics, coin, numismatic sources, methodology, X-ray fluorescence analysis, digital numismatics, Northern Black Sea region, monetary circulation, die analysis, topography of coin finds.

CUVINTE-CHEIE: numismatică, monedă, surse numismatice, metodologie, analiză prin fluorescență cu raze X, numismatică digitală, nordul Mării Negre, circulație monetară, analiza ștanțelor, topografia descoperirilor monetare.

1. Problem Statement

Modern numismatics, like virtually all branches of scholarly inquiry, is undergoing a methodological transformation that is changing its status within the system of the humanities. On the one hand, new tools are emerging for the study of the coin as the principal numismatic source; on the other hand, the coin itself is increasingly understood as a complex socio-cultural phenomenon. Numismatic material is being integrated into the theoretical frameworks of the material turn, digital humanities, social anthropology, and semiotics. A transition is taking place from description to interpretation, from the recording of features to the analysis of functions, contexts, and interactions. The coin is thus conceptualized as a factor in historical processes that shapes the economic, political, and symbolic structures of society.

Within contemporary approaches, the coin is interpreted as a multimodal object that combines economic value, artistic imagery, and material substance. Chemical composition, metal microstructure, traces of wear, die links, and

spatial patterns of distribution are considered equally significant components of the source, making it possible to combine the micro-analysis of individual specimens with broader macro-historical generalizations.

The digitalization of research and the use of Big Data, network analysis, and geographic information systems (GIS) are forming a new infrastructure for numismatic studies. The coin appears as a node within networks of economic and cultural connections, opening possibilities for reconstructing coin emissions, the logistics of circulation, and regional models of monetary circulation.

2. Analysis of Recent Research

An analysis of recent studies demonstrates the active implementation of new methodological paradigms in the study of ancient and medieval numismatics. A key point of reference has become the “material turn,” which emphasizes the coin as a physical object possessing its own technological “biography.” For instance, archaeometric and natural-scientific methods have significantly expanded the possibilities of the “geography of metal.” X-ray fluorescence analysis enables the verification of coins and the identification of alloy changes as indicators of crisis phenomena¹, while the digital reconstruction of corrosion phases in copper and bronze allows patina to be interpreted as a diagnostic instrument².

The digital revolution (Digital Humanities) has transformed numismatics into a high-tech field of research. The theoretical foundations for the use of web resources and online platforms in the study of medieval coin typology have been substantiated by V. Orlyk³, while the systematization of issues related to the digitalization of numismatic research has been undertaken in the dissertation of O. Shvets⁴. The project “Finds of Ancient Greek Coins in Ukraine” (led by M. Pyzyk (USA) and V. Orlyk (Ukraine)), implemented according to the LOD standard, integrates Ukrainian data into Nomisma.org and demonstrates the possibilities of digital verification.⁵

An integrative approach combines the micro-analysis of artefacts with macro-historical generalizations, as illustrated by the identification of a new type of Olbian drachm. The development⁶ of 3D scanning⁷, network analysis, and electronic auction archives⁸ has created a new research infrastructure, complemented by algorithmic recognition methods.⁹

The socio-cultural dimension is represented by studies of the legends and monograms of Olbia¹⁰, as well as by the digital iconographic project IMAGNUM.¹¹ The “spatial turn” is reflected in topographic studies and research on barbarian imitations.¹²

3. Presentation of the Main Research Material

The contemporary development of science and technology creates new opportunities for research across various fields of knowledge, including ancient and medieval numismatics, significantly expanding the toolkit for the application of traditional methods in numismatic studies (typological, chronological, iconographic, epigraphic, metrological, die analysis, statistical methods, topography of finds, comparative-historical and contextual approaches, etc.), while also shaping new methods of scholarly inquiry. In this context, particular attention will be paid to the development of three key methods of numismatic research which, in the authors’ view, have undergone significant qualitative transformations in recent decades.

In particular, the metrological method has received new impetus through the development of metallographic and physicochemical analyses employing X-ray fluorescence analysis. In contemporary numismatic studies, with the consolidation of the “material turn” paradigm, the coin is regarded not only as a sign of state authority or a medium of exchange but also as a physical object possessing its own technological “biography,” chemical composition, and material agency. Such a “new realism” places emphasis on the study of coin alloys, the microstructure of metals, minting techniques, and traces of circulation, thereby opening possibilities for reconstructing economic and social

¹ Indutny, Pirkovich, Dyshlova-Hrynyuk 2024.

² Bokhan, Kormosh, Kropivnyi 2025.

³ Orlyk 2013.

⁴ Shvets 2025.

⁵ Pyzyk 2024; Pyzyk 2025.

⁶ Orlyk, de Callatay, Kolesnichenko 2025.

⁷ Shvets, Bondarenko, Kotsur 2025.

⁸ Boyko-Haharin, Kotsur, Tyshchenko 2024.

⁹ Pasichnyk, Rizhniak 2024.

¹⁰ Nikolaev 2024.

¹¹ Peter, Stolba 2025.

¹² Orlyk 2023; Orlyk, Pyzyk 2023; Röttger 2025; Orlyk, Pyzyk, Orlyk 2025.

processes. The metrological method and metallographic as well as physicochemical analyses are complementary: the former records the quantitative parameters of the monetary standard, while the latter reveals the material and technological foundations of these parameters. Their combined application ensures the most comprehensive reconstruction of the monetary system and the economic policy of the corresponding period.

A key role in this process is played by archaeometry as the integration of natural-scientific methods into the humanities. X-ray fluorescence analysis makes it possible to determine the chemical composition of coin metal without causing physical damage to the specimen. The isotopes of lead, copper, and silver allow researchers to identify sources of raw materials, distinguishing, for example, silver from Laurion from that originating in Spanish or Cypriot deposits. Such data refine existing interpretations of the economic autarky of poleis, demonstrate interregional interdependence, and enable the analysis of resource crises and trade restrictions in the ancient and medieval periods. Archaeometry thus appears not merely as an auxiliary but as an interpretative tool that connects the material characteristics of coins with evidence relating to mining, financial reforms, and military campaigns. Examples of the successful application of X-ray fluorescence analysis in studies of ancient and medieval numismatics include the works of Z.Stos-Fertner and T.Florkowski¹³, H.Gitler, & M.Ponting¹⁴, V. Orlyk¹⁵; A.Inberg, D.Ashkenazi, M.Cohen, N.Iddan and D.Cvikel¹⁶, E.Jonsson¹⁷, M.Crosera, E.Baracchini, E.Prenesti, A.Giacomello, B.Callegher, P.Oliveri and G.Adami¹⁸, Z.Al-Saad and M.Rababah¹⁹, M. Orlyk and I.Prokhnenko²⁰, V.Indutny, K.Pirkovich and V.Dyshlova-Hrynyuk²¹, V. Orlyk and F. de Callataÿ²², Ž.Šmit and A.Šemrov²³, 2025, V.Orlyk and V.Kropivnyi²⁴ et al.

It was precisely the Polish physicists Zofia Stos-Fertner and Tadeusz Florkowski who tested the potential of the radioisotope X-ray fluorescence method for detecting heavy metal impurities in Kufic silver coins. The authors convincingly demonstrated the effectiveness of spectral analysis as a tool that enables rapid and sufficiently sensitive determination of elemental composition without damaging the numismatic material.²⁵ However, despite early attempts to apply X-ray fluorescence analysis, its widespread adoption in research practice occurred only in recent decades. A decisive role in this process was played by the emergence of portable spectrometers, which became technically accessible due to the development of compact X-ray tubes with wavelengths of 0.05 – 10 nm and an energy range of 0.1–25 keV. The establishment of serial production of such equipment significantly expanded the possibilities for studying metal artefacts of the past. This, in turn, contributed to a noticeable increase in the number of studies devoted to the analysis of numismatic materials – coins and coin dies – which is reflected in a number of the contemporary publications mentioned above.

One of the directions of modern numismatic studies is the quantitative analysis of wear and die series. The loss of weight as a result of circulation is used to model the intensity of monetary circulation and to distinguish between active use and hoarding. The analysis of die life makes it possible to estimate the scale of coin emissions and the overall volume of money supply. The material parameters of coins, from the structure of the alloy to the technique of striking – reflect the level of administrative control and the organization of mints within centralized and polycentric systems. The active introduction of quantitative methods into numismatics has significantly expanded the analytical capabilities of researchers; however, it has also brought to the fore the problem of methodological risks. The application of mathematical models to historical material requires not only technical accuracy of calculations but also a critical reflection on the limits of their applicability. The transfer of statistical tools into the field of humanities without proper adaptation may lead to erroneous generalizations or to the excessive formalization of complex historical processes. A demonstrative example is the use of Sturges' formula to determine the number of grouping intervals in variation series. In a number of numismatic studies, particularly in the works of A. L. Ponomarev²⁶, Sturges' formula is used as a basic instrument for constructing histograms and for the subsequent analysis of weight distributions. However, in modern statistics this rule is regarded only as

¹³ Stos-Fertner, Florkowski 1975, 43.

¹⁴ Gitler, Ponting 2006.

¹⁵ Orlyk 2016; Orlyk 2021.

¹⁶ Inberg et al. 2018.

¹⁷ Jonsson 2018.

¹⁸ Crosera et al. 2019.

¹⁹ Al-Saad, Rababah 2020.

²⁰ Orlyk, Prokhnenko 2023a; Orlyk, Prokhnenko 2023b.

²¹ Indutny, Pirkovich, Dyshlova-Hrynyuk 2024.

²² Orlyk, Callataÿ 2024.

²³ Šmit, Šemrov 2025.

²⁴ Orlyk, Kropivnyi 2025.

²⁵ Stos-Fertner, Florkowski 1975, 3.

²⁶ Ponomarev 2002; Ponomarev 2011.

a rough empirical estimate suitable primarily for small samples and data close to a normal distribution. As early as 1995, the Australian statistician Rob J. Hyndman (Monash University) emphasized that Sturges' formula does not meet the requirements of modern statistical practice and should not be used as a standard recommendation in textbooks or software²⁷. Subsequent research in the theory of histograms and density estimation has confirmed its limitations: it tends to underestimate the number of intervals in large samples, which leads to a loss of information about the structure of the data. In contemporary statistical packages, the Scott rule or the Freedman–Diaconis rule are increasingly used as alternatives, as they better account for variance and sample size.

In the context of quantitative numismatics, this issue is of fundamental importance. An incorrectly determined number of intervals may artificially smooth out or, conversely, exaggerate the presence of weight “clusters,” which are interpreted as the consequences of monetary reforms, changes in standards, or the functioning of several emission centres. Thus, the uncritical use of statistical formulas may lead to erroneous historical and economic conclusions. Modern statistical theory regards Sturges' rule as historically significant but methodologically limited. It is based on the assumption that the distribution approximates a normal distribution and has a logarithmic dependence on sample size, which leads to an “oversmoothing” of data in large assemblages of coin material. In quantitative numismatics, this may artificially obscure the existence of multiple weight standards or emission phases. Therefore, the application of the Scott or Freedman–Diaconis rules, or the use of kernel density estimation methods, appears to be methodologically more appropriate.

A significant methodological dimension is represented by the concept of the “biography of things,” which traces the life cycle of a coin, from the extraction of metal to its withdrawal from circulation. Physical traces of wear, overstrikes, or various forms of “demonetization” record changes in the functions of the coin.²⁸ In ancient and medieval contexts, coins could serve not only as means of payment but also as ornaments, amulets, or bullion silver by weight, which reflects not economic degradation but rather a transformation of symbolic value. From this perspective, the coin appears as an active agent within social relations, shaping trust, legitimacy, and perceptions of stability.

A separate and exceptionally complex task of modern ancient numismatics is the identification of monograms and abbreviations with real historical individuals. As O.M. Zograf²⁹ aptly noted, the decipherment of monograms belongs to the most difficult and least “rewarding” problems of the discipline, since only a few interpretations immediately gain general acceptance. An interpretation acquires historical significance only when the name can be reliably associated with a person attested by other sources in the corresponding time and place.

Illustrative in this regard are the hypotheses concerning the legends of Olbian coins of the fifth century BC (APIXO, ΘΥ), which have been correlated with individuals mentioned by Herodotus. In particular, the Scythian king Scyles has been associated with Orikos (Ὀρίκος) and Tymnes (Θύμνιος). In general, the interpretation of monograms constitutes a lengthy process of eliminating alternative explanations and requires clearly defined methodological principles.

Recent advances in the study of ancient numismatics, particularly the coinage of Olbia, have been associated with the development of prosopography and the synchronization of the eponym catalogue IPE I² 201 (4th–1st centuries BC). The reconstruction of genealogies of elite families has made it possible to correlate abbreviations on coins with the names of eponyms and magistrates dated with a precision of approximately 5–20 years³⁰.

Certain principles of interpretation have also been established. When a particular community has been sufficiently studied, prosopography begins to play a leading role in reconstructing even fragmentarily preserved names, including those appearing in coin legends. The higher the social status of an individual, the more diverse sources attest to that person – in decrees, dedications, stamps, and coins. Equally important is the tradition of hereditary transmission of names, which is reflected in the recurrence of monograms and abbreviations across different generations, and occasionally even in the hereditary nature of magistracies themselves. Within a single emission, a simplification of monograms can often be observed, while their relative placement may provide clues for correct interpretation.

Such a methodological approach presupposes the synthesis of prosopographical reconstructions with numismatic classification. A group of reconstructed magistrates' names within a narrow chronological framework should correspond to a specific coin sub-group or type. If a particular abbreviation falls outside the typological context, its interpretation requires reconsideration. Thus, the combination of prosopography, epigraphy, and numismatic typology significantly increases the reliability of identifying monograms with real historical individuals and minimizes the risk of arbitrary reconstructions.

²⁷ Hyndman 1995.

²⁸ Gorini 2017; Skoryy, Khokhorovski 2018; Daragan, Polin 2022; Nadvirnyak, Pohorilets, Kiyko 2025.

²⁹ Zograf 2005.

³⁰ Nikolaev 2024; Ніколаєв 2024b.

The digital revolution has become a defining factor in the formation of contemporary methodological paradigms in the study of ancient and medieval numismatics. This development involves not merely the renewal of research tools but a reconsideration of the very logic of investigation: from the analysis of individual specimens and local collections to the processing of large datasets (Big Data) within the framework of Digital Humanities. Within this system, the coin appears not as an isolated artefact but as an element of a global information network, making it possible to model economic, political, and cultural processes at the level of regions and empires.

A key instrument of this transformation is the technology of Linked Open Data (LOD), which ensures semantic compatibility between databases, museums, and research centres. The platform Nomisma.org has standardized data concerning rulers, mints, and coin types, creating a unified intellectual environment for the automated correlation of information. A practical example is the project Online Coins of the Roman Empire, initiated by the American Numismatic Society, which integrates traditional corpus publications with open digital collections and transforms the conventional catalogue into a networked system of interconnected data.

Methodologically, Linked Open Data represents a transition from a linear organization of knowledge to a graph-based architecture in which the coin functions as a node linking information about the issuing authority, metal composition, circulation area, and archaeological context. This enables the systematic modelling of the dynamics of the spread of coin types, emission cycles, and centres of economic activity.

One of these methods is the use of numismatic databases as a tool for the topography and cartography of coin finds. This approach is employed in such projects as Coin Hoards of the Roman Empire (hereafter CHRE)³¹ at the University of Oxford, the Digital Atlas of Roman and Medieval Civilizations (hereafter DARMC)³² at Harvard University and Framing the Late Antique and Early Medieval Economy (hereafter FLAME)³³ at Princeton University.

Databases represent structured systems for storing and organizing information and serve as the foundation for the operation of many electronic resources. The way information is organized within them depends on their type: relational databases (SQL) and systems designed for working with unstructured or semi-structured data (NoSQL).³⁴

In the CHRE project, the database functions as the primary instrument for the spatial analysis of coin hoards. Each hoard within the system is assigned a geographical reference, chronological parameters, and a structured description of its composition, which allows the generation of interactive distribution maps and enables regional and chronological comparisons. Within the DARMC project, the database likewise serves as a tool for cartographic representation, though within a broader historical-geographical framework. Numismatic data may be integrated as separate layers within a GIS environment alongside administrative boundaries and trade routes, allowing the distribution of coins to be correlated with political, economic, and social processes.

In contrast to the two aforementioned projects, within the FLAME project the database serves as the central methodological instrument for the topography of coin finds. It not only accumulates information but also directly generates cartographic models of coin distribution in both space and time. A distinctive feature of database use in this project is that spatial cartography is combined with a critical analysis of data structure. Methodologically, the project takes into account regional distortions (bias) and the uneven representation of different countries within the structured dataset intended for further analysis, research, or processing. Consequently, within FLAME the database functions simultaneously as both an archive and the analytical core of GIS modelling.

This method of database application developed gradually as a complex digital infrastructure. The project coordinator M. Pyzyk notes that FLAME developed two principal components – the minting module and the circulation module – which operate using a relational database and geospatial software³⁵. The implementation of these modules led to a transition from the simple storage of data to their full cartographic visualization, whereby the database began to function not merely as an archive but as the operational core of cartographic analysis. During the process of entering each record of a find into the database (including coordinates, typology, dating, and context), the data are directly integrated into the GIS environment.

However, when applying such a digital method, it is important to consider that spatial cartography cannot be conducted without accounting for regional imbalances in the collected datasets³⁶, as well as the distinction between primary and secondary distortions.³⁷ Thus, it can be stated that in contemporary methods of topography the database

³¹ CHRE: <https://chre.ashmus.ox.ac.uk/>

³² DARMC: <https://harvard-cga.maps.arcgis.com/apps/webappviewer/index.html?id=9e7b4e361f5940d5bd399ec6c2ca2197>

³³ FLAME: <https://coinage.princeton.edu/>

³⁴ Shvets 2025.

³⁵ Pyzyk 2021.

³⁶ Pyzyk 2021, 198.

³⁷ Pyzyk 2021, 200.

is not neutral. Rather, it represents a conditioned corpus conditioned historically and by publicationally shaped – that requires critical interpretation prior to cartographic analysis, while the composition of particular structured datasets directly influences the resulting spatial patterns.³⁸

As can be observed, databases function as the analytical core of historical and economic reconstruction, and the method itself is transformed into a sequence of stages: the collection and standardization of data, the integration of information into a relational structure, the georeferencing of records, visualization within a GIS environment, and subsequent interpretation with consideration of possible distortions. This approach makes it possible to identify clusters, distinct zones, dynamic changes, and regional asymmetries in the monetary circulation of the ancient and medieval periods.

The use of databases as an instrument for topography performs three principal functions: an archival function involving the accumulation of structured data; an analytical function involving spatial modelling; and a critical function that takes into account distortions and uncertainties. It is precisely this combination that transforms the database, within the framework of the method considered, from an auxiliary tool into a central methodological element in the topography of coin finds.

Digital technologies have also significantly modernized the method of die analysis. The Ukrainian scholar O. Shvets quite rightly notes that «today, with the possibilities of using both a basic set of tools for conducting numismatic research and modern equipment, information technologies, or software, there exist four main known methods of comparative die analysis: visual, manual graphic, graphic using specialized software, and machine (automated)».³⁹

An important direction of the digital paradigm is the application of artificial intelligence and computer vision⁴⁰. Machine learning algorithms automate the comparison of images and the identification of die links, which is of fundamental importance for refining estimates of the scale of coin emissions. In contrast to the traditional manual comparison of thousands of specimens, neural networks enable both the intensification and increased accuracy of analysis. Studies of Roman denarii and medieval pennies have demonstrated the possibility of revising production volumes and reconstructing the internal organization of mints. Thus, artificial intelligence transforms not only the technical toolkit but also the methodology of interpretation, shifting research from selective examination toward the comprehensive processing of large corpora of data.

In general, the digital revolution is reorienting numismatics from a descriptive corpus-based discipline toward an analytical network-based model. Linked Open Data technologies integrate global resources, artificial intelligence automates die analysis, and GIS modelling reconstructs economic zones and logistical vectors. Within this paradigm, the coin appears as a digital object embedded within a global system of knowledge. At the same time, contemporary methodology considers it not merely an economic instrument but also a means of communication and a carrier of symbolic codes that shape representations of power and social reality within the frameworks of social anthropology and semiotics.

4. Conclusions

A comprehensive reconsideration of ancient and medieval numismatics within the framework of contemporary methodological paradigms demonstrates its transformation into a multidimensional instrument of historical reconstruction. The field is evolving from a descriptive discipline into an integrative domain of interdisciplinary knowledge, opening new possibilities for the analysis of economic, political, and cultural processes in a long-term historical perspective. The coin thus appears not as an illustrative source but as a material, digital, and symbolic object in which technology, power, and the market intersect.

The material turn and “new realism” emphasize the physical characteristics of coins, while archaeometry, isotopic and X-ray fluorescence analyses, and the statistical study of wear allow for the reconstruction of the geography of metal, the scale of coin emissions, and the dynamics of circulation. The biographical approach complements this perspective by revealing changes in the social functions of coins depending on the cultural context.

³⁸ FLAME's Datasets: <https://coinage.princeton.edu/flames-datasets>

³⁹ Shvets 2023, 293.

⁴⁰ Zambanini, Kampel 2011; Arandjelović 2012; Huber-Mörk et al. 2012; Taylor 2020.; Heinecke et al. 2021; Ulichev et al. 2025.

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