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DEVELOPMENT OF ARCHAEOLOGICAL HERITAGE GEOPORTALS IN RUSSIA AND THE WORLD: COMPARATIVE ANALYSIS AND PROSPECTS FOR INTEGRATION[1]

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The article deals with a comparative analysis of Russian and foreign experience in creating geoinformation platforms for archaeological heritage. It analyzes the transformation of systems from visualization tools to multifunctional environments that provide analysis, monitoring, and management of cultural heritage sites. Based on a study of leading global projects (ARIADNE, Archaeology Data Service, National Heritage Board Geoportal, Swedish National Data Service, etc.), three key models have been systematized: global research infrastructures, applied accounting systems, and specialized analytical platforms. It has been revealed that their successful functioning is based on strict international metadata standards (CIDOC CRM, FAIR principles) and interoperability. Russian geoportals have been analyzed in detail, from the national Archaeological Map of Russia to the regional systems of Crimea, Mordovia, and Tatarstan. It has been established that, despite significant progress in integrating archival and modern data and implementing spatial analysis tools, their development is hindered by systemic fragmentation, the lack of a unified standardization system, and a project-based funding model. The paper argues for the need to transition to a hybrid network model that combines a centralized federal portal and flexible regional platforms to fully integrate Russia's digital archaeological heritage into the global scientific landscape.

Keywords: archaeology, geoportals, archaeological heritage, geoinformation systems (GIS), metadata standardization, interoperability, spatial data infrastructure, digital archaeology, heritage protection.

РАЗВИТИЕ ГЕОПОРТАЛОВ АРХЕОЛОГИЧЕСКОГО НАСЛЕДИЯ В РОССИИ И МИРЕ: СРАВНИТЕЛЬНЫЙ АНАЛИЗ И ПЕРСПЕКТИВЫ ИНТЕГРАЦИИ[2]

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Статья посвящена сравнительному анализу российского и зарубежного опыта создания геоинформационных платформ археологического наследия. Анализируется трансформация систем от средств визуализации к многофункциональным средам, обеспечивающим анализ, мониторинг и управление объектами культурного наследия. На основе изучения ведущих мировых проектов (*ARIADNE*, *Archaeology Data Service*, *National Heritage Board Geoportal*, *Swedish National Data Service* и др.) систематизированы три ключевых модели: глобальные исследовательские инфраструктуры, системы прикладного учета и специализированные аналитические платформы. Выявлено, что их успешное функционирование базируется на строгих международных стандартах метаданных (*CIDOC CRM*, принципы *FAIR*) и интероперабельности. Детально проанализированы российские геопорталы – от национальной «Археологической карты России» до региональных систем Крыма, Мордовии и Татарстана. Установлено, что, несмотря на значимый прогресс в интеграции архивных и современных данных и внедрении инструментов пространственного анализа, их развитие сдерживается системной фрагментацией, отсутствием единой системы стандартизации и проектной моделью финансирования. Обосновывается необходимость перехода к гибридной сетевой модели, сочетающей централизованный федеральный портал и гибкие региональные платформы, для полноценной интеграции цифрового археологического наследия России в глобальное научное пространство.

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Ключевые слова: археология, геопорталы, археологическое наследие, геоинформационные системы (ГИС), стандартизация метаданных, интероперабельность, инфраструктура пространственных данных, цифровая археология, охрана памятников.

Archaeological Heritage Geoportals: From Visualization to Integration Challenges. The creation of geoinformation systems for interactive access to spatial data has become a priority area of GIS technology in archaeology. Implemented as geoportals, these systems provide web maps and geoservices, helping to study and protect historical and cultural heritage sites. In this environment, experts, government institutions, and the public can visualize, analyze, and manage data about archaeological monuments. This is an important step towards integration into national and international spatial data infrastructures (NSDI/NPD), but the implementation is hindered by the lack of a unified system for standardizing spatial data and services in Russia that ensures interoperability (Koshkarev, 2022).

Today, geoportals go beyond simple visualization, becoming a multifunctional digital environment for comprehensive analysis, monitoring the status of objects, and supporting management decisions. The main task is to overcome data fragmentation by implementing mandatory industry standards that comply with international practices, which will create a fully functional national infrastructure capable of integration into global scientific networks.

A comparative analysis of Russian and foreign approaches. Russia has a number of departmental and regional solutions (e.g., the Russian Geographical Society's geoportal and the Ministry of Culture's sectoral systems), but there is no unified national platform for archaeology. In contrast, foreign countries have well-developed national and international infrastructures, such as ARIADNE (European Union) and Archaeology Data Service (United Kingdom), which aggregate vast amounts of data. Russia's key challenge is the lack of a unified system for standardizing metadata, data formats, and data exchange protocols, which hinders the collaborative use of data. Foreign services solve such issues by implementing universal standards (CIDOC CRM, OGC services, and FAIR principles) that ensure the interaction of heterogeneous systems. Thus, despite the plans to create a national spatial data infrastructure, the main challenge remains overcoming fragmentation through a unified system of standardization.

Foreign experience in creating digital platforms and archives. An analysis of foreign projects allows us to identify three groups: global research infrastructures, applied record-keeping and heritage protection systems, and specialized analytical and visualization platforms.

1. Research systems. These include global and national projects aimed at long-term archiving, standardization, and integration of digital data to support open science. Their goal is to create a sustainable environment that ensures the preservation, accessibility, and semantic compatibility of diverse information arrays. Examples include ARIADNE Research Infrastructure, Archaeology Data Service, Swedish National Data Service, and IANUS.

ARIADNE Research Infrastructure AISBL is a leading European research system for integrating archaeological digital collections and archives. The project, which was carried out in two stages (2012-2016 and 2018-2022), brought together more than 3.5 million diverse digitized resources from 40 countries. The technological foundation of the project is cloud computing and virtual research environments with search, visualization, and geotemporal analysis services. The data is standardized using the RDF format, the CIDOC-CRM ontology, and the principles of linked open data, which allows for the use of artificial intelligence methods (Meghini et al., 2017). However, interoperability remains a challenge due to differences in the structure of national archives, the complexity of unifying interfaces, and the limited participation of small organizations.

Archaeology Data Service (ADS) is an open access digital archive of the University of York (UK, established in 1996), providing long-term storage, curation and access to digital materials of archaeological research – from reports to 3D models (Richards, 1997). The work is based on the OAIS (Open Archival Information System) model, guaranteeing data preservation. The ArchSearch portal integrates metadata from national monuments registers and local archives, creating a single point of access to distributed resources. And the open access policy makes ADS an important tool for education and science. However, the project faces a number of challenges

typical of research infrastructures. The main challenges include dependence on grant funding, the complexity of processing outdated formats and large amounts of data, and a focus on British and European collections. Nevertheless, ADS remains a key element of the international digital archaeology ecosystem, whose expertise and verified data serve as an important foundation for larger integration projects such as ARIADNE.

Swedish National Data Service (SND) is a national service for storing research data, including archaeological data, in Sweden (Jakobsson, 2021). Since 2008, the service has been operated as a consortium of universities with a distributed network of local units (DAUs – Data Access Units), providing scientists with comprehensive support at all stages of data management, from project planning to the publication of complex geospatial and three-dimensional materials. SND strictly follows international standards (such as OAIS and FAIR principles) and acts as an important national hub in European research networks, which significantly increases the integration and visibility of Swedish archaeological data in the global scientific community. Sustainability is ensured by government funding, but the decentralized architecture makes it difficult for users to navigate; access to some data is limited, and materials in Swedish create a language barrier.

IANUS (Forschungsdatenzentrum Archäologie & Altertumswissenschaften, Germany) is the national portal for long–term storage and open access to digital data of archaeology and classical antiquities. The project is coordinated by the German Archaeological Institute, and since 2020 it has been developing within the framework of the National Data Research Infrastructure (NFDI), being part of the NFDI4Objects consortium. Главная его задача – обеспечить сохранность и доступность уникальных данных, полученных в ходе археологических раскопок. The resource offers the scientific community three main services based on strict international standards: the development of specialized recommendations for long-term archiving for the entire range of archaeological data, data storage in accordance with the OAIS standard in its own infrastructure or with partners with a guarantee of long-term availability, as well as ensuring access to data through the portal in accordance with the FAIR principles (Schäfer, et al, 2013). The strengths include expert support led by the German Archaeological Institute and integration into the national NFDI infrastructure to ensure sustainability, as well as active practical support for researchers during the data preparation phase. Among the weaknesses and current challenges, the transition period for infrastructure updates, which temporarily limits services, the technical complexity of the archiving process for end users, and the dependence of success on the willingness of scientific institutions to implement new data management practices stand out.

2. *Applied accounting and heritage protection systems.* These platforms are focused on state accounting, monitoring, and data integration into the system of urban planning and legal protection, which makes them a working tool for authorities and specialized services. A notable example is the National Heritage Board Geoportal (Poland).

The Geoportal of the National Heritage Board of Poland is a comprehensive information system created within the framework of the INSPIRE directive and provides online access to data on more than 100,000 architectural and archaeological monuments listed in the state register (Fiedukowicz et al, 2018). The system goes beyond basic data publication, offering advanced multi-level cartographic visualization and serving as a working tool for heritage protection services, spatial planning, and scientific research.

The portal is based on a hierarchical classification of objects, which is displayed using icons (category, class, type) and color coding by century or historical era. The detail of information changes automatically in the scale range from 1:1,000 to 1:1,500,000. At small scales, an innovative cartographic matrix is used to group objects by administrative units and quantitative indicators by type. The dynamic legend adapts to the current scale and visible elements, and the switch between architectural and archaeological profiles allows for relevant display of chronological attribution. The portal's deep visualization and user-centric approach have made it a sought-after platform. The main challenges lie in handling large and diverse datasets, and the portal has implemented innovative solutions to overcome these challenges.

3. *Specialized analytical and visualization platforms.* The third group of systems is focused on scientific interpretation and reconstruction of the past, rather than on administrative

record-keeping or archiving. These resources integrate diverse spatial data (archaeological, environmental, and remote sensing data) in geoinformation systems to address research and educational challenges, such as modeling ancient landscapes and societal dynamics. An example is the international web-based atlas ArchAtlas.

ArchAtlas (https://www.archatlas.org/welcome/, accessed on 23.12.2025) is an international scientific and educational web project focused on visualizing and studying the spatial processes of the prehistoric and early historical eras. The platform functions as a digital atlas that integrates archaeological, cultural, and natural data in a geoinformation environment, allowing for the reconstruction of historical landscapes and the analysis of the dynamics of ancient societies, including the spread of agriculture, the formation of trade networks, and the development of urbanization. The main focus is on scientific interpretation using spatial analysis methods and remote sensing data (CORONA satellite images, Quickbird satellite images, and SRTM digital elevation models). The resource combines the publication of visual essays with the organization of scientific seminars and remains an open, free tool for researchers, teachers, and students, providing systemic interdisciplinarity by connecting archaeological evidence with geographical context and information about the ancient environment.

At the same time, ArchAtlas has a number of limitations due to its specialization. Since the project is not designed to solve cadastral, monitoring, or legal tasks, its functionality for government agencies responsible for heritage management is significantly reduced. The completeness and accuracy of information directly depend on the activity of individual research initiatives, which leads to fragmentation and uneven geographical coverage. Despite the availability of reliability assessments, the verification of data uploaded by different researchers requires users to perform independent checks. The web interface is primarily focused on visualization and basic search, without offering advanced statistical or complex spatial analysis tools. Additionally, effective use (such as interacting with KML files) requires a certain level of technical proficiency.

Thus, ArchAtlas is an important example of specialized research infrastructure in digital archaeology, whose main value lies in supporting scientific interpretation and interdisciplinary visualization of the past. Its architectural and methodological solutions serve as a promising foundation for similar projects specializing in the reconstruction of historical processes. However, these same features also limit its applicability in the field of practical cultural heritage management and conservation, where different functional priorities and data standards are required.

In addition to the platforms discussed, there are many other digital resources dedicated to the recording and study of archaeological heritage in the world, such as the National Register of Historic Places (NRHP, USA), the Historic Environment Record (HER, UK), and the Archaeological Resource Guide for Europe (ARGE). However, there are significant limitations for Russian researchers to fully utilize these systems. One common issue is the national legal specificity and the focus on domestic users, as well as political restrictions that completely block access to certain European resources.

Russian Geoinformation Platforms in Archaeology: Architecture, Capabilities, and Limitations. The digitalization of archaeological science and heritage protection in Russia is manifested in the development of various types of geoinformation resources, from the national "Archaeological Map of Russia" to regional geoportal systems in Crimea, Mordovia, and Tatarstan, which focus on monitoring, legal protection, comprehensive data visualization, and scientific analysis. Analyzing their architecture, functionality, methodological framework, and existing limitations allows us to assess the current state, potential, and directions of digitalization of archaeological heritage in the country.

"Archaeological Map of Russia" (Institute of Archaeology of the Russian Academy of Sciences, https://archaeolog.ru/pub/map, accessed on 24.11.2025) is a large-scale scientific project that has been implemented since 2014 with the support of grants from the Russian Science Foundation and the Russian Foundation for Basic Research. The database contains information about more than 70,100 archaeological sites, which are organized based on typological, chronological, and spatial criteria. For data processing, the automated information processing system "Terek" has been developed, which is based on the methodology of the archaeological monument passport, created in the 1970s and 1980s for the all-Union program "The Collection of Historical and Cultural Monuments of the Peoples of

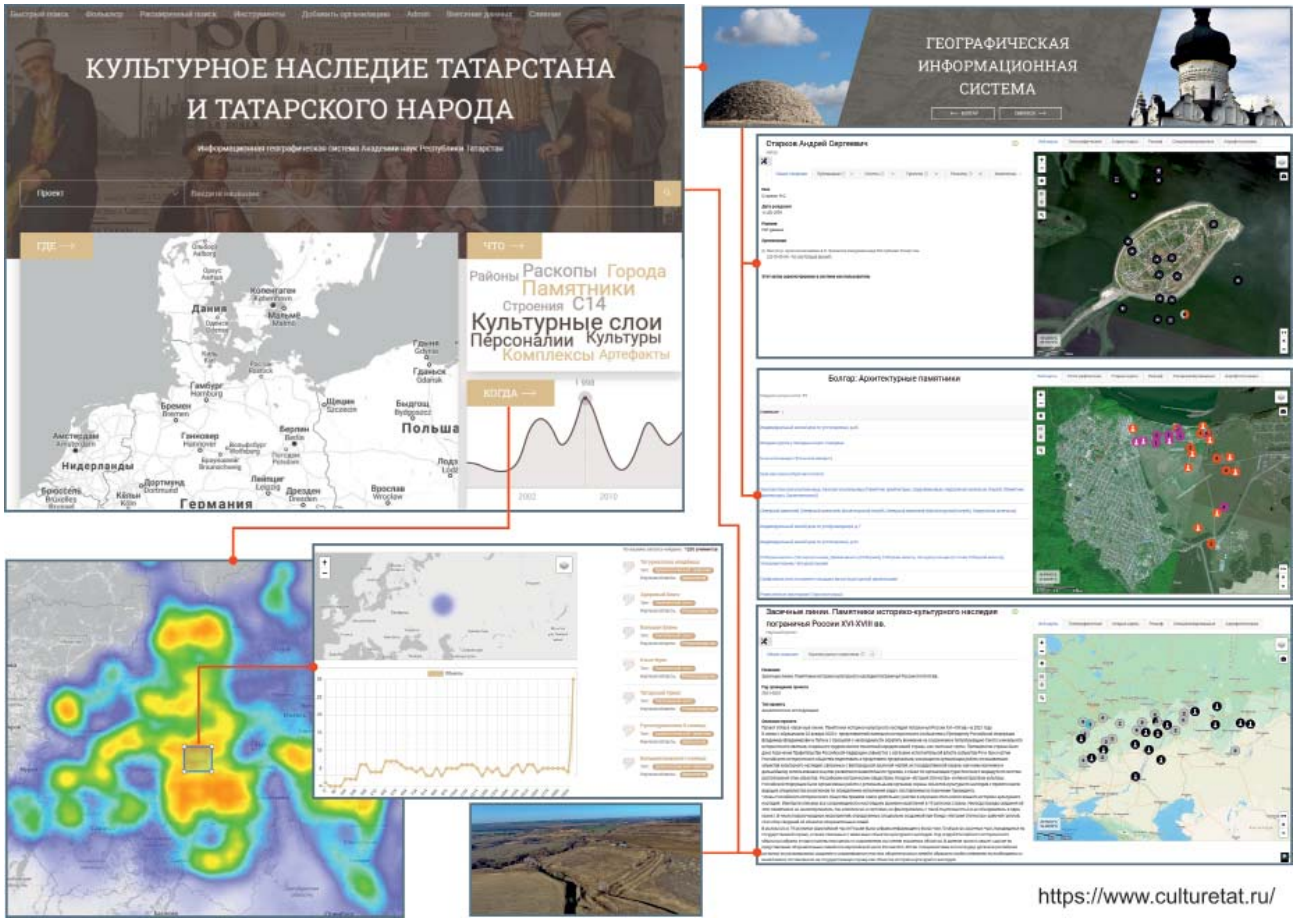


Fig. 1. User interface of the Cultural Heritage of Tatarstan and the Tatar People geoinformation system
Рис. 1. Пользовательский интерфейс геоинформационной системы «Культурное наследие Татарстана и татарского народа»

Russia." The input, search, administration, and visualization subsystems use the public services of Yandex.Maps and OpenStreetMap (Makarov et al., 2015).

The scientific value of the portal is determined by its comprehensive methodology: modern research data with GPS coordinates is combined with archival materials from 1944-1965, whose localization has been restored based on field reports from the Institute of Archaeology of the Russian Academy of Sciences. To protect against looting, the public version hides the exact coordinates, and nearby monuments are aggregated. For objects that are not at risk, accurate coordinates and related scientific materials are available. The system also includes information about trenches and excavations without a cultural layer, allowing users to assess the level of archaeological exploration in the area.

The advanced filter system allows you to create thematic maps and conduct spatial analysis. A special emphasis is placed on the popularization of knowledge: the visualization of "invisible" monuments in the landscape helps users understand the uniqueness and vulnerability of the cultural layer. The portal is designed as a central link in the state registration system, combining the functions of a scientific reference book and an analytical tool for fundamental research and practical protection of Russia's archaeological heritage.

The Geoportal "Archaeological Monuments of Crimea" (https://crimgeoarch.bsuedu.ru/, accessed on December 23, 2025) is a regional GIS developed by the Belgorod State National Research University for the spatial analysis of archaeological heritage sites, taking into account their legal status and land use. The unified geodata base includes both officially registered and unregistered monuments; their combination with layers of land use and administrative-cadastral division has made it possible to identify

areas where the current regime threatens the preservation of heritage (Buryak, Lisetskii, Ilyashenko, 2018).

The technical basis is a multi-level geodatabase in the ArcGIS 10.5 environment. The central ArchSite point layer is supplemented with vector layers, and the end-to-end geo_ID identifier links the archaeological block to the administrative, cadastral, and land-use blocks, automatically determining the cadastral plot, land-use type, and administrative affiliation for each monument. The data accuracy is ensured by cross-checking with state registers, territorial planning materials, literature, and expedition reports, as well as by deciphering high-resolution satellite images (2014-2017) to verify objects that are poorly visible in the terrain (kurgans and settlements), mapping 12 types of land based on OpenStreetMap, and integrating up-to-date cadastral information through the WMS service of the Federal Service for State Registration, Cadastral Records, and Cartography. This comprehensive approach not only allowed for the creation of an up-to-date register, but also enabled the implementation of automated analysis tools to identify critical situations, such as the location of monuments.

The functionality available to authorized users (representatives of government agencies and scientific institutions) includes visualization of objects together with cadastral boundaries, multifunctional search, basic geoinformation operations, as well as remote editing and replenishment of the database for continuous monitoring. The implemented analytical tools provide automated identification of the above-mentioned threats.

The main limitations are related to the closed nature of access, which, while protecting monuments from looting, hinders integration into the national spatial data infrastructure (NSDI) and narrows the range of users. Additional difficulties are created by the dependence on proprietary software, which limits interoperability, and the uneven completeness of external sources in different regions of Crimea. However, the methodology and architecture of the geoportal have significant potential for replication in other regions of Russia. However, to fully realize this potential, including integration into NAPs and expanding the user audience, it will require addressing issues of data openness, standardization, and long-term technical support.

The Geoportal "Natural and Cultural Heritage of Mordovia" (https://map.rgo.life/, accessed on 23.12.2025) is an interdisciplinary project of the Ogarev Mordovia State University, implemented with the support of the Russian Geographical Society. The project aims to comprehensively digitalize, popularize, and educate about the historical, cultural, and natural potential of the region (Yamashkin, Yamashkin, 2023). The interactive map combines 2,869 spatially referenced objects and is complemented by an online encyclopedia. The archaeological block is represented by the Archaeology thematic layer, which integrates data on the age, cultural affiliation, and continuity of the monuments, providing insight into the archaeological landscape.

The portal is distinguished by its openness and educational focus, which are achieved through the interdisciplinary integration of archaeological, ethnographic, architectural-historical, natural, and tourist-recreational data into a holistic information model of the region. The scientific and methodological basis is based on modern GIS technologies and remote sensing methods, which has been confirmed by numerous publications. The system is actively used in the educational process as a tool for developing specialized competencies.

At the same time, from the perspective of professional archaeology, the resource has limitations. The educational orientation leads to a generalized format of presenting information: there is no detailed primary documentation (field reports) or systematic legal linking of monuments to cadastral data and protected areas. The relevance and development of the content depend on the sustainability of the project team and stable funding. Thus, the Natural and Cultural Heritage of Mordovia portal is an effective tool for presenting heritage to a wide audience, but it does not replace specialized archaeological GIS that focus on inventory, spatial analysis, and legal protection of objects.

The geoinformation system of the Academy of Sciences of the Republic of Tatarstan "Cultural Heritage of Tatarstan and the Tatar People" (https://www.culturetat.ru/, accessed on 23.12.2025) was created by the Academy of Sciences of the Republic of Tatarstan. The project was launched in 2011 as part of a comprehensive study of Bolgar and Sviyazhsk, and by 2018 it had been expanded to a universal integration platform

(Vyazov et al., 2021; Sitdikov, Saifutdinova, Mukhametshin, 2023; Khamidullin et al., 2023; Borodulin et al, 2025; Baranov et al, 2025).

More than 230 employees of academic institutions and universities participated in the data collection, resulting in a system that includes over 100,000 objects: 1,500 architectural monuments, 16,500 archaeological sites, 20,000 cultural layers, 13,700 archaeological complexes, and 2,500 individuals.

The data is georeferenced. The structure is based on a flexible model that allows for both objective and interpretive attributes, which is especially valuable when describing controversial or lost objects. It provides multi-user access with a role-based system (administrator, author, and user), where the author of the research project has priority in editing related data and can restrict access to changes after verification.

The cartographic module includes a multi-layered service with web maps, topographic and historical materials (including general land survey plans), and terrain and aerial photography data. The search tools include "Quick Search" and "Advanced Recursive Search," which use relationships between objects and allow you to limit the search area to an arbitrary polygon on the map. The analytical module offers cluster analysis, Bayesian statistical chronological analysis (for radiocarbon dating), and principal component analysis. Sample results are exported in .csv, .json, and ESRI .json formats, and are also saved as a ready-made map in .png format with a legend.

The platform's limitations are related to its regional focus, as the focus on Tatarstan limits the possibilities for interregional comparisons. The quality and completeness of the content vary depending on the activity of the scientific community, resulting in uneven data distribution across periods or types of monuments. The multi-user editing mode requires continuous professional moderation to avoid conflicts of interpretation. The technical platform relies on a graph database and modern web frameworks, which places higher demands on IT staff and computational resources.

Consequently, the "Cultural Heritage of Tatarstan and the Tatar People" system represents a notable contribution to the digitalization of Russia's cultural heritage, offering an effective tool for the integration, analysis, and popularization of diverse data (Sayfutdinova et al, 2025, p. 273–282). Despite certain limitations, the geoportal's architectural solutions (graph data model, client-server architecture) and functional features can serve as a methodological foundation for similar developments in other regions.

In addition to publicly available resources, a number of regional and departmental geoinformation systems in the field of archaeology are known in domestic practice. These include specialized tools (such as the Archeograph system developed by the Institute of Archaeology and Ethnography of the Russian Academy of Sciences), local databases (such as the database of archaeological research in the city of Kirov developed by VyatSU), and the creation of GIS resources in the Stavropol and Krasnoyarsk regions, Udmurtia, Kalmykia, Chukotka, and other regions of the country. However, due to their fragmentation and lack of

Table 1. Comparative Analysis of Russian and Foreign Archaeological Heritage Geoportals
Таблица 1. Сравнительная характеристика российских и зарубежных геопорталов археологического наследия

Aspect	International experience	Situation in Russia
Level of development	Established national and international systems (e.g., ARIADNE, ADS) that aggregate data from multiple sources	Disparate departmental and regional solutions, the stage of forming a unified infrastructure
Key problem	Ensured by the implementation of unified standards (CIDOC CRM, OGC services, FAIR principles) that guarantee interoperability	Lack of mandatory metadata standards, formats, and exchange protocols that prevent systems from being compatible (interoperable)
Approach to integration	Integration is a basic function: data from local repositories is automatically transferred to shared catalogs through standardized interfaces	Integration is a long-term goal, but data fragmentation and inconsistencies in the regulatory framework hinder the creation of NPDs
Funding	Predominantly software and institutional funding that ensures long-term sustainability	The project (grant) model prevails, leading to the termination of support and updating after the completion of projects

a centralized open catalog, these developments remain isolated, and their data and functionality are difficult to access for the scientific community. This fragmentation is natural in a situation where each system is created for specific local tasks and does not rely on common metadata standards and exchange protocols, which ultimately limits their use beyond individual projects.

A comparative analysis of archaeological heritage geoportal systems in foreign countries and the Russian Federation revealed and systematized fundamental differences in architectural, functional, and methodological approaches (Table 1). While international practices demonstrate a high level of development based on unified metadata standards and exchange protocols, which makes integration a fundamental feature of systems, Russia's approach is characterized by fragmented departmental and regional solutions, and centralized standardization and platform compatibility remain a promising goal rather than a achieved result.

Conclusion. The conducted comparative analysis of Russian and foreign archaeological heritage geoportals showed that global practice is developing towards standardized, interoperable, and sustainable digital environments that combine data based on the FAIR principles and the OAIS model. Leading international projects (ARIADNE, ADS, SND, IANUS) demonstrate that integration is becoming not an additional option, but a basic function supported by unified metadata standards and exchange protocols, as well as programmatic institutional funding.

Domestic experience, represented by both national (Archaeological Map of Russia) and regional systems (Crimea, Mordovia, Tatarstan), confirms significant progress in integrating archival and modern sources, implementing spatial analysis, and protecting monuments. However, key barriers remain systemic fragmentation, the absence of mandatory national standards, the prevalence of project-based funding, and the resulting instability of many platforms. As a result, even the most advanced Russian geoportal systems remain local and poorly compatible with each other and international infrastructures.

The prospects for the digitalization of archaeological heritage in the country are associated with the transition from fragmented initiatives to a coordinated hybrid network model. Such a model should include a centralized federal portal that sets unified metadata standards and serves as a basic registry, as well as a network of flexible regional and thematic platforms that can exchange data through standardized interfaces. Critical conditions for success include the legalization of requirements for formats and protocols, the creation of mechanisms for long-term programmatic funding of support infrastructures, the development of analytical tools, and the controlled openness of data for the scientific community. Implementing this approach will not only help to overcome the current fragmentation, but also ensure the full integration of Russia's digital archaeological heritage into the national and international scientific community.

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About the Author:

Sayfutdinova Guzel M. Candidate of Technical Sciences. Institute of Archaeology named after A.Kh. Khalikov, Tatarstan Academy of Sciences. Bauman St., 20, Kazan, 420111, Republic of Tatarstan, Russian Federation; Associate Professor. Institute of Geology and Petroleum Technologies, Kazan (Volga Region) Federal University. Kremlyovskaya St., 18, Kazan, 420000, the Republic of Tatarstan, Russian Federation; saif_gm@mail.ru

Информация об авторе:

Сайфутдинова Гузель Маратовна, кандидат технических наук, заведующий отделом, Институт археологии им. А.Х. Халикова Академии наук Республики Татарстан; доцент кафедры, Институт геологии и нефтегазовых технологий Казанского (Приволжского) федерального университета (г. Казань, Россия); saif_gm@mail.ru

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