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From data collection to analysis: Designing a relational database for archaeological research in the eastern Rhodope region

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ABSTRACT

This paper aims to demonstrate the potential of relational databases for archaeological purposes in storing, organizing, managing, querying, and analysis of various types of data. This results in exploration of the long-term settlement history of a regional landscape. The organization and analysis of spatial and non-spatial archaeological datasets pose significant challenges for archaeologists, particularly when it comes to integrating data from multiple sources, representing spatial relationships among data elements, and accommodating multiple scales of analysis. In recent years, advances in database technologies have enabled archaeologists to organize these datasets more effectively through the application of relational databases. This study focuses on the design of a relational database for the eastern Rhodope region in Bulgaria, with the further goal of investigating settlement patterns through the identification, mapping, and analysis of archaeological sites and their spatial relationships. The aim of this research is to explore how archaeologists can enhance their analysis of complex datasets by adopting relational database design, which enables effective organization and integration of data from various sources.

KEYWORDS

Archaeological relational database, spatial reference, PostgreSQL, PostGIS, organizing data, query analysis

Introduction

Archaeologists face unique challenges in organizing and analysing large and complex datasets. These challenges stem from the multidisciplinary nature of archaeological research, which often involves integrating data from diverse sources, representing spatial relationships among data elements, and accounting for multiple scales of analysis. To overcome these challenges, researchers have turned to relational databases as a way to store, manage, and analyse archaeological data. Relational databases provide an effective solution for organizing and integrating data from various sources and establishing connections between data elements based on spatial and temporal correlations.

However, designing and implementing an effective relational database for archaeological data represents a complicated task. The data is often heterogeneous, complex, and subject to a wide range of analytical approaches. Furthermore, the design of the database must consider the unique requirements of archaeological data, such as the need to represent spatial relationships among data elements, the importance of context in interpreting data, and the need for data quality control.

This study presents the design and implementation of a relational database for organizing and analysing spatial and non-spatial archaeological datasets from the eastern Rhodope region in Bulgaria[1]. The database was designed and tailored to the unique requirements of archaeological data and implemented using open-source software[2]. A further purpose of the database is to investigate the settlement patterns of the eastern Rhodope region. The study of settlement patterns involves the identification, mapping, and analysis of archaeological sites as well as their spatial relationships.

The focus of this study is to explore how archaeologists can enhance data management and analysis for complex archaeological datasets by implementing best practices in the design of relational databases that take into account integration, spatial relationships, and multiple scales of analysis. The methodology section outlines the collection of available and very diverse data resources for the eastern Rhodope region, the relational database design, and the data collection methods used to populate the database with archaeological and environmental data. The archaeological relational database of the eastern Rhodope region result section presents the tables of archaeological data, environmental data, raster data, and natural resources data that were generated by the database. The discussion section analyses the potential of the database in organizing complex archaeological datasets and the challenges faced during the implementation process. Finally, the conclusion provides an overview of the paper and suggests areas for further research on archaeological database design and management.

Methodology

Available resources

The primary source of archaeological data for this study was the archaeological information system "Archaeological Map of Bulgaria" (AIS AKB) (Archaeological Map of Bulgaria 2023), which collects data from various sources, including archaeological excavations, field surveys and other investigations. The data is geographically organized and provides detailed information on the location, function and chronology of each archaeological site.

To supplement the archaeological data, reports and publications related to archaeological research in the Eastern Rhodope region were also reviewed. These sources provide valuable information on the chronology, location, and nature of archaeological sites and artefacts, as well as the excavation and analysis methods used. They also provide a historical and archaeological context to help understand the significance of the findings. Other parts of the gathered data come from ancient sources. However, their data is incomplete and should be examined with caution. Artefacts from collections, often without any background and other surface materials not collected systematically or scientifically, may still provide helpful information to complete the general picture.

Another important point of any archaeological research is the environmental data such as rivers, lakes, geology, soils, and elevation. This set of background map data is a useful spatial framework for archaeological study (Conolly et al. 2006, 41). Environmental data was obtained mainly from the Japan international cooperation agency (JICA) project (Baseynova direktsiya 'Iztochnobelomorski rayon'. Izsledvane za integrirano upravlenie na vodite v Republika Bulgaria, yuni 2006 – mart 2008, 2021). The data obtained from the JICA project includes information about rivers, lakes, geology, soils, and the modern territorial division of Bulgaria. The environmental data also includes digital elevation contour derived from the SRTM DEM file described further below.

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1 It is part of the author's PhD thesis "Settlement system between the Maritsa and Arda river valleys in the Eastern Rhodope – GIS-based spatial analysis based on data from the Archaeological Map of Bulgaria".

2 The database is implemented by applying the PostgreSQL database management system and the PostGIS spatial extension.

The data on past natural resources was obtained from various places, including publications about archaeological surveys and excavations, and geological surveys. In addition, recent archaeological surveys have provided valuable information on ancient mines and mineral deposits in the region (Popov, Iliev 2006; Popov 2012; Georgiev 2007a, b, c; Popov, Jockenhövel 2018, 204). Several field surveys conducted in the municipality of Krumovgrad have identified and documented the remains of ancient mining activities in the area (Popov, Iliev 2006; Popov et al. 2009; Popov 2011; Popov et al. 2015; Georgiev 2012; Georgiev, Popov 2019; Georgiev 2020). In recent years, several studies have been conducted in the eastern Rhodope region focusing on archaeomineralogy and geoarchaeology (Kostov et al. 2007; Kostov 2010, 2013; Kostov et al. 2016).

The database includes a range of raster data, such as the Lidar digital terrain model (DTM), and old aerial photographs, which were obtained from various sources. The Shuttle Radar Topography Mission Digital Elevation Models (SRTM DEMs) were used to provide elevation data for the entire region, with a spatial resolution of approximately 30 m. The SRTM DEM was freely downloaded (USGS. Earth Explorer 2021). In addition to the SRTM data, Lidar data was obtained from the National Archaeological Institute with Museum at the Bulgarian Academy of Sciences. This data is available only for some parts of the eastern Rhodope region. It is high-resolution elevation data with sub-meter accuracy. Recently, it has been used in archaeological surveys in the region as a tool for mapping and identifying archaeological features (Nekhrizov et al. 2016; Georgiev, Popov 2019; Nekhrizov et al. 2019). Old aerial photographs from 1963 were obtained from the Military Mapping Centre of the Ministry of Defence.

Relational database design

The design of the relational database was based on the entity-relationship model. This model presents separate tables with a coherent package of information and a relation between all values stored within (Codd 1970; Lock 2003, 89–90). A data model establishes how data should be organized and related. Based on the data model, a database schema is created, which is a more inclusive and elaborate description of the model. The database schema includes tables, columns, and relationships. In a relational database, each table represents a specific type of data or entity. For example, one table may contain information about archaeological sites, while another may include information about artefacts found at those sites. These tables are linked together through common fields, such as site ID or artefact ID, allowing for complex queries and data analysis (Fisher 1994, 37–38). Creating a relational database design is not easy because it requires a thorough understanding of the data and the relationships between the data. A well-designed database should store and retrieve data while maintaining data integrity and consistency.

Data relationships also make it possible to easily search and sort the range of visual and textual information. The researcher can gain a comprehensive insight into the archaeological record using cross-referential queries. There could be as many relations/tables as needed within the database. The relationships between the tables are of different types (one-to-one; one-to-many; many-to-many). In order to deal with the data and to maintain “referential integrity”, strict rules are applied on new data being incorporated. For instance, the addition of information regarding an object into a table is prohibited if there is no record concerning the same object in an associated table. These rules allow us also to easily carry out cross queries (Cheetham 1992; Farinetti 2009, 34). Relational databases also enforce data integrity by design via pre-defined rules that ensure that data is entered accurately and consistently. These ensure the data is reliable and can be used for subsequent analysis. Users can also define custom data types, which are helpful when working with specialized data. Such custom types make it easier to store and analyse diverse datasets such as site data, environmental data, natu-

Context						
context_id	site_id	sector	square	context	layer	level
1	53	Center	J 40	pit	none	1.27 m

Artefacts						
item_id	context_id	site_id	item	material	size	description
10	1	53	blade	iron	9.8 x 0.4 x 1.5	Part of an iron blade with a flat section
18	1	53	mill stone	rock	30 x 23 x 22	Fragment of mill stone
33	1	53	awl	bone	9.4.x 0.9	A fragment of a bone awl

Fig. 1. Example of the relations between two tables in an archaeological relational database: the "artefacts" table and the "context" table. These tables are linked together through a many-to-many relationship, meaning that multiple artefacts can be found in a single context, and multiple contexts can contain the same artefacts (figure by V. Gencheva)

Обр. 1. Пример за връзките между две таблици в археологическа релационна база данни: таблицата "артефакти" и таблицата "контекст". Тези таблици са свързани помежду си чрез връзка много към много, което означава, че множество артефакти могат да бъдат намерени в един контекст и множество контексти могат да съдържат едни и същи артефакти (автор В. Генчева)

ral resources data, and raster data. The specific datasets to be used depend on the research questions being addressed and the available data sources.

They can also allow different levels of access based on roles, i.e., the roles of reader, contributor and admin. The reader role provides read only access, the contributor can also write, while admin can update and delete as well. These roles, once defined, can then be distributed amongst the researchers.

The database was designed and implemented using PostgreSQL with the PostGIS spatial extension (PostgreSQL Documentation 2023), which proved to be a suitable platform for the analysis. PostgreSQL is a popular, open-source, relational database management system (RDBMS). RDBMS is software that manages the creation, maintenance, and use of relational databases. An RDBMS provides tools and interfaces to manage the database, including defining the database structure, creating, and modifying tables, querying, and manipulating data, and enforcing data integrity constraints. PostGIS is an extension for PostgreSQL that adds support for geospatial data. These tools provide a wide range of functions and methods for storing, manipulating, and analysing geospatial data.

Data organization

Data structure is the actual physical arrangement of the data. It is essential for the types of operations that will be performed and the results that can be obtained. The types of query analysis are also greatly affected by it. When arranged and classified properly, processing and analysis are more efficient. The relational database allows us to structure our information at multiple levels, each related to the others. That permits archaeologists to compare data from different sites and time periods. Essentially, during the creation of the database the datasets are deconstructed into the smallest possible logical groups, while applying careful analysis of both the data itself and the problems it addresses. The practical value of breaking down data in this way is efficient management. Redundant, repetitive, and irrelevant data is identified and removed, and analytical goals are explicitly stated. The analytical value of this process is that it allows new relationships and patterns to emerge.

The creation of the eastern Rhodope database required the collection and integration of heterogeneous spatial and non-spatial archaeological data from various sources and periods. The challenge of organizing this data into a coherent spatial form or a consistent structure was addressed through a time-consuming and labour-intensive process. Each piece of information was carefully analysed to determine its relationship to other data in the database, and decisions were made regarding how to standardize the data to ensure it could be easily queried and analysed. It was important to ensure that the different data sources could be related to each other in a meaningful way. For example, there are tables for archaeological sites, artefacts, and contexts. Each of them represents a different type of information. To relate this data, each table may have a unique identifier, such as a site ID, artefact ID, or context ID. This identifier is used to link information from one table to another. If an artefact is found in a specific context, the artefact table would include the context ID as a foreign key (fig. 1). By organizing and relating archaeological data in this way, it becomes possible to perform complex analyses and gain a better understanding of the relationships between different types of data, and it is possible to retrieve information from all of the related tables. Despite these challenges, the effort put into data collection and entry has resulted in a valuable resource for understanding the archaeology of the eastern Rhodope region.

Archaeological relational database of the eastern Rhodope region. Results

The creation of the archaeological relational database of the eastern Rhodope region has resulted in an organized repository of archaeological data. The database includes information about almost 2000 archaeological sites, including their location, chronology, context, and associated artefacts. In addition, a significant amount of geospatial data was integrated into the database. That allowed for a more holistic understanding of the region's archaeology and its relationship with the landscape. Through the use of relational database technology, the data has been organized and linked in a meaningful way, allowing for complex queries and analysis. The database has facilitated the identification of new relationships and patterns in the data, as well as the identification of gaps in the existing knowledge of the region.

The eastern Rhodope database is designed with a relational structure (fig. 2), where tables are connected through spatial and temporal correlations that link entities, such as sites, contexts, and artefacts. At the core of the database is a table dedicated to archaeological sites, which acts as the central hub for the other interconnected tables. All of the files are presented as either vector data, such as points, lines, and polygons or raster data. Several tables implemented in the database are described below.

Tables with archaeological data

Sites table

The archaeological site table contains essential information about each site, such as its site ID, name, type, chronology, spatial coordinates, and a brief description. As the main table in the database, every other table in the system has a relationship with this central table. Controlled domains with predefined values are used for fields like type and chronology to guarantee consistency. A site type is divided according to the defined site function like settlement, necropolis, cult place, road, fortification, etc., and all its subdivisions are adjusted according to the AIS AKB structure. Site chronology contains chronologies from the Palaeolithic to the Bulgarian Revival period, including different periods or phases recorded by archaeologists. That allows for consistent usage of terms and easy cross-database analysis. A numerical system is employed before the chronological data to maintain

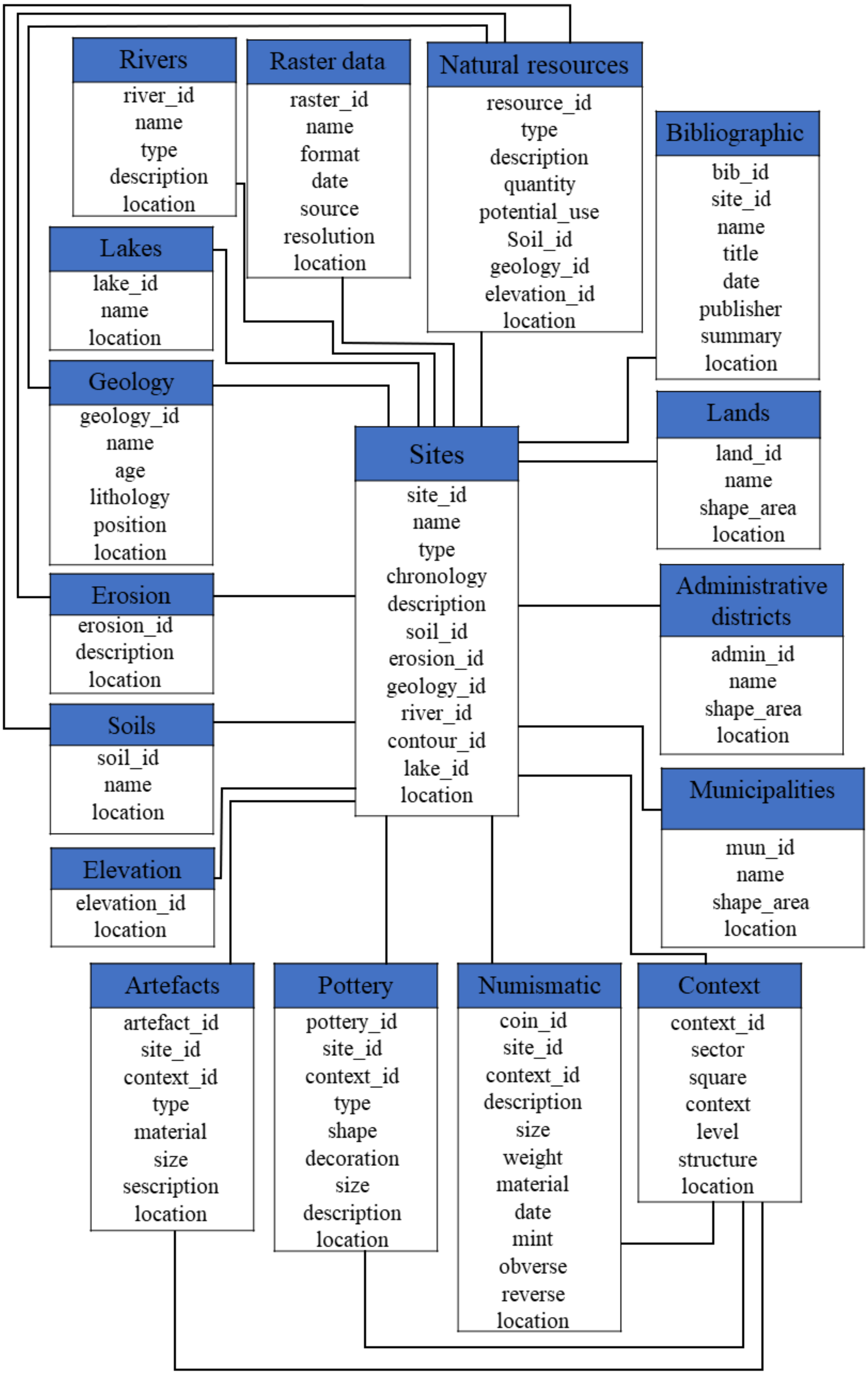

Fig. 2. Eastern Rhodopes database structure. Relations between different tables (figure by V. Gencheva)
Обр. 2. Структура на базата данни за района на Източните Родопи. Връзки между отделните таблици (автор В. Генчева)

chronological order, preventing the software from ordering it alphabetically by default. An example of this is the “2.3 Roman period”. The data in this table is presented by a point geometry, providing location information for each site.

Context table

The context table contains data from some of the excavated sites provided by the archaeologists. It includes sector, square, context, arbitrary level, and structure from different sites. The data is represented by a point geometry. While this information is important to understanding the context of each site, it is not always complete due to a lack of published data. This table is linked to other tables in the archaeological database, such as the artefacts and pottery tables, using common fields like site ID and context ID.

Artefacts table

The artefact table contains basic fields with data about the collected artefacts (excluding pottery and coins) and their type, material, size, and description. This data is represented by a point geometry within the database. This table is closely related to the tables for sites and context, and these relationships are established using common fields such as site ID and context ID. For artefacts that have stratigraphic information as a result of excavations, the table includes additional fields for X, Y, and Z coordinates.

Pottery table

The pottery table contains vital information about the ceramics discovered at different sites. This table includes fields for the type of pottery, shape, decoration, size, and description. The data is represented by a point geometry. In addition to locally produced pottery, the pottery table also includes information about imported pottery. It’s worth noting that the amount of published data on pottery can vary widely depending on the site and the level of archaeological investigation. In some cases, there is access to detailed information about every piece of pottery found. In other cases, the information may be more limited, with only basic details recorded.

Numismatic table

The numismatic data table is set up as a separate table in order to accommodate its unique set of archaeological and historical information. It is specifically designed to store detailed information about coins found at different archaeological sites. In addition to the coin’s description, size, weight, and material type (“Gold”, “Silver”, “Bronze”, and “Copper”), the table also includes columns for the coin’s date, mint, and the design on both the obverse and reverse sides. Additionally, it includes a field for any hoards that may shed light on the historical context of the coins. The location where they were found is also recorded using X and Y coordinates. This table is still in its initial phase of being populated because numismatic data is often scarce and difficult to obtain. Additionally, the analysis of coins requires specialized knowledge, which can limit the number of researchers who can contribute to this aspect of the archaeological record.

Tables with environmental data

Rivers table

The rivers table contains information about the modern location of rivers and their attributes, such as name, type and description. The data is represented by line geometry, which allows mapping and analysis of the river network concerning the surrounding landscape. The ‘Nearest Neighbor’ function is used to establish a relationship between the site table and the river table. This function determines the nearest river in terms of distance to each archaeological site and represents it in the database. Additional data on the width and depth of the rivers could provide insights into the natural environment and its potential impact on past human activities, but the available resource in the JICA geodatabase does not contain such data.

Lakes table

The lakes table contains information on the geographical coordinates and names of modern lakes in the study area. The location of each lake is represented by a polygon geometry, which provides a visual representation of the extent of the water body. Metadata, such as information on the coordinate reference system, is also included to ensure accurate analysis and interpretation of the data. Furthermore, this table is also linked with the archaeological sites table using the ‘Nearest Neighbor’ function, which allows for the calculation of the distance between each archaeological site and the nearest lake.

Geology table

The geology table contains detailed information on the modern geological formations and stratigraphy of the area surrounding the sites. The table includes fields for the name of each formation, its geological age, lithology, and stratigraphic position. Each formation is represented by a polygon geometry, which shows its extent in the study area. The geology table is linked with the archaeological sites table using the ‘Within’ function, allowing the users to determine which archaeological sites are located within each geological formation.

Soils table

The soils table provides valuable information on the soils present at each archaeological site. The table includes fields for the name of each soil formation, and a polygon geometry that represents the spatial extent of each soil type. By linking this data with the archaeological sites table using the ‘Within’ function, it is possible to determine which soil types are associated with each site. Metadata on the coordinate reference system is also included. Additional fields for pH, organic matter, and texture would provide important information about soil properties that can affect the preservation of archaeological artefacts. Unfortunately, this data is not currently available.

Erosion table

The erosion table contains information about the specific area where erosion was observed and description about the type of erosion process that occurred, such as wind erosion, water erosion, or gravitational erosion. This table is also linked with the archaeological sites table using the ‘Within’ function, allowing to determine which archaeological sites are located near or within each erosion area. The data is represented by polygon geometry.

Digital elevation contour table

The table is presented by line geometry and provides data on the elevation of each site. Furthermore, it is linked to the archaeological sites table via the ‘Nearest Neighbor’ function, establishing a relationship between the two datasets.

Table with raster data

The raster data table contains several geospatial datasets. These datasets include SRTM DEMs and their derivatives, such as slope, hillshade, and aspect. The table also includes Lidar DTM (digital terrain models), which provides highly accurate information on the terrain. Georeferenced old aerial photographs from 1963 are also included in this table, allowing researchers to identify changes in the landscape over time and gain insights into the history of human activity in the area. The table includes essential attributes for each dataset, such as the name, file format, date of acquisition, source, resolution, and location. Metadata, including information on the coordinate reference system, is also included to ensure accurate analysis and interpretation.

Natural resources table

The natural resources table includes information about the various resources types available in the past, such as wood, minerals, metal ores, and clay. The table is designed to capture detailed information about each resource, including type, description, quantity, potential use, location and metadata about the coordinate reference system. The potential use contains information of the known uses of the resource (e.g. construction material, decorative element, toolmaking). The location field is implemented by a point geometry.

Modern territorial division

There are several tables for the modern territorial division of Bulgaria. They are useful for the internal organization of the archaeological sites.

Administrative districts table

The district table includes information about the largest administrative units within the study area. It includes fields for the district name, the area size, location and metadata about the coordinate reference system. Each district is represented as a polygon geometry, which allows for spatial analysis and mapping.

Municipalities table

The municipalities table includes information about the middle-sized administrative units within the study area. It contains fields for the name, shape area, location, and metadata about the coordinate reference system. Each municipality is represented as a polygon geometry, which allows for spatial analysis and mapping.

Lands table

The Lands table includes information about the smallest administrative units within the study area. It contains fields for the name, shape area, and location. Each different land is represented as a polygon geometry, which allows for spatial analysis and mapping.

Bibliographic table

The bibliographic table includes information about publications encompassing fields for the author, title, publisher, year of publication, volume, issue, pages and ISBN or ISSN. This table is informative for tracking the sources used in an archaeological research project and ensuring proper citation in publications or reports.

Population of the database is ongoing work that requires extensive data collection, processing, and analysis. The database is continually being updated with new information gathered from fieldwork, archival research, and other sources. In addition, data quality control measures are implemented to ensure the accuracy and consistency of the information in the database. As the database expands, new tables and relationships between entities may be added to accommodate the growing complexity of the data. The goal of this ongoing work is to develop a comprehensive and reliable resource for studying the settlement history and cultural landscape of the eastern Rhodope region.

Discussion

The use of relational databases has become increasingly popular in the field of archaeology for organizing large amounts of data (Keller 2009). Relational databases offer a great deal of flexibility in terms of data storage and analysis, allowing archaeologists to integrate diverse types of data. In addition, the use of spatial analysis tools within them provides a powerful way to visualize and understand the relationships between archaeological sites and the landscape in which they are situated. In spite of all the advantages, one should take into account some of the disadvantages of using relational databases, including such as some IT skills and the time-consuming nature of designing tables, relationships, and queries, ensuring that the data is organized in a meaningful way. Most of these drawbacks are valid when working with diverse and non-consistent data.

Several examples outlined below show the potential use of the designed archaeological relational database with spatial extension for the eastern Rhodope region. Different query analyses were executed to investigate the distribution patterns of rock-cut tombs in the Eastern Rhodope region

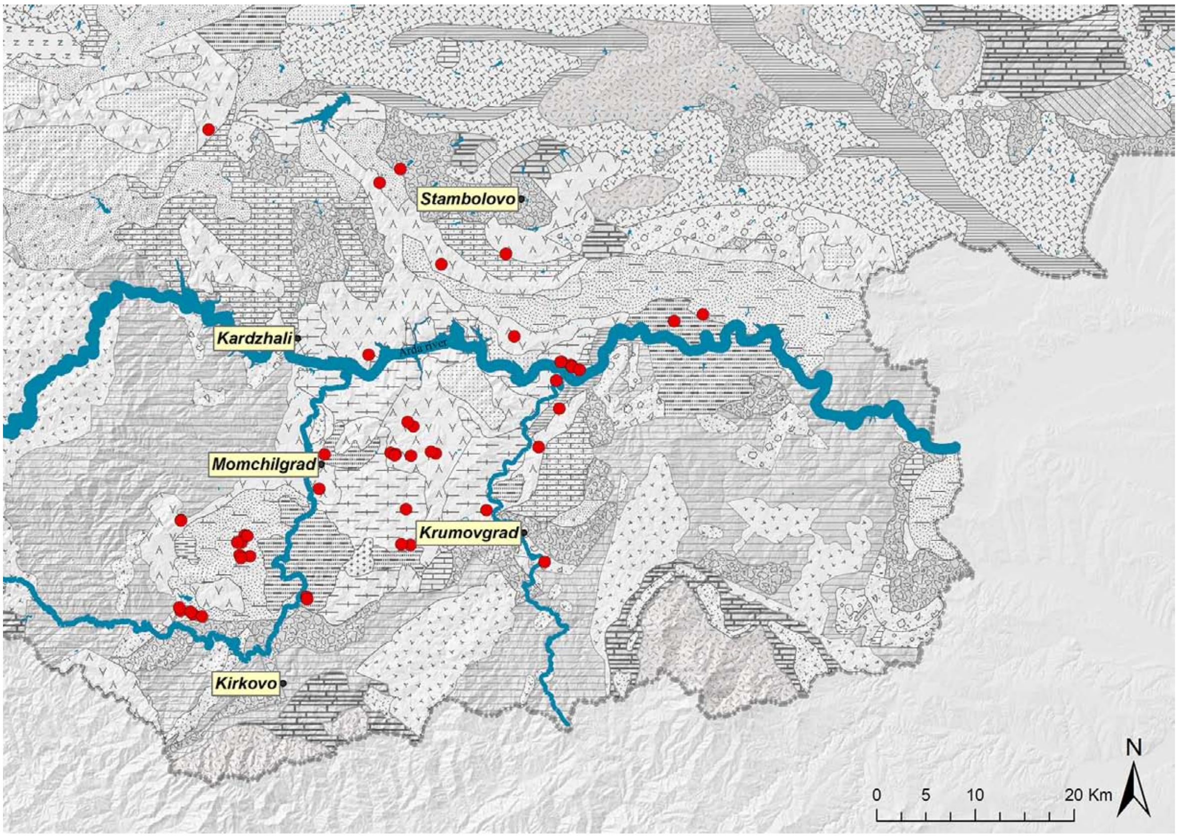

Fig. 3. Geological map (Baseynova direktsiya 'Iztochnobelomorski rayon'. Izsledvane za integrirano upravlenie na vodite v Republika Bulgaria, yuni 2006 – mart 2008, 2018) and localization of rock-cut tombs in the eastern Rhodope region, SE Bulgaria. Rivers are marked with blue lines. The rock-cut tombs are marked with red dots. Background map: SRTM DEM (USGS. Earth Explorer 2021) (figure by V. Gencheva)
Обр. 3. Геоложка карта (Baseynova direktsiya 'Iztochnobelomorski rayon'. Izsledvane za integrirano upravlenie na vodite v Republika Bulgaria, yuni 2006 – mart 2008, 2018) и локализация на скални гробници в района на Източните Родопи, Югоизточна България. Реките са маркирани със сини линии. Скалните гробници са маркирани с червени точки. Фонова карта: SRTM DEM (USGS. Earth Explorer 2021) (автор В. Генчева)

according to their geological background, clustering and nearest settlement sites.

The eastern Rhodope region has been a subject of archaeological research for many years, and its rich history is reflected in the numerous monuments and ancient structures that mark the landscape. One of the challenges in studying these monuments is understanding their distribution patterns and the factors that influenced their location. A query analysis was implemented to retrieve data on the geological background of the rock-cut monuments. The results showed that the distribution of rock-cut tombs is closely related to the prevalence of tuffs and sandstone, which are both easy for carving rocks (fig. 3). These results support earlier observations made by other researchers for the locations of rock-cut tombs (Kostov 2008; Nekhrizov 2015, 134).

In order to further deepening of the analysis, additional algorithms were used for better understanding the clustering of rock-cut tombs (Density-Based Spatial Clustering of Applications with Noise algorithm). This algorithm identifies clusters of closely packed points in high-density regions and marks isolated points in low-density regions as noise or outliers. The result was identification of several clusters of rock-cut tombs (fig. 4). To ensure the accuracy of the analysis, various factors that may impact the distribution patterns were taken into account. For instance, the presence of water bodies was considered, such as the full-water rivers of Arda, Varbitsa, and Krumovitsa. These rivers

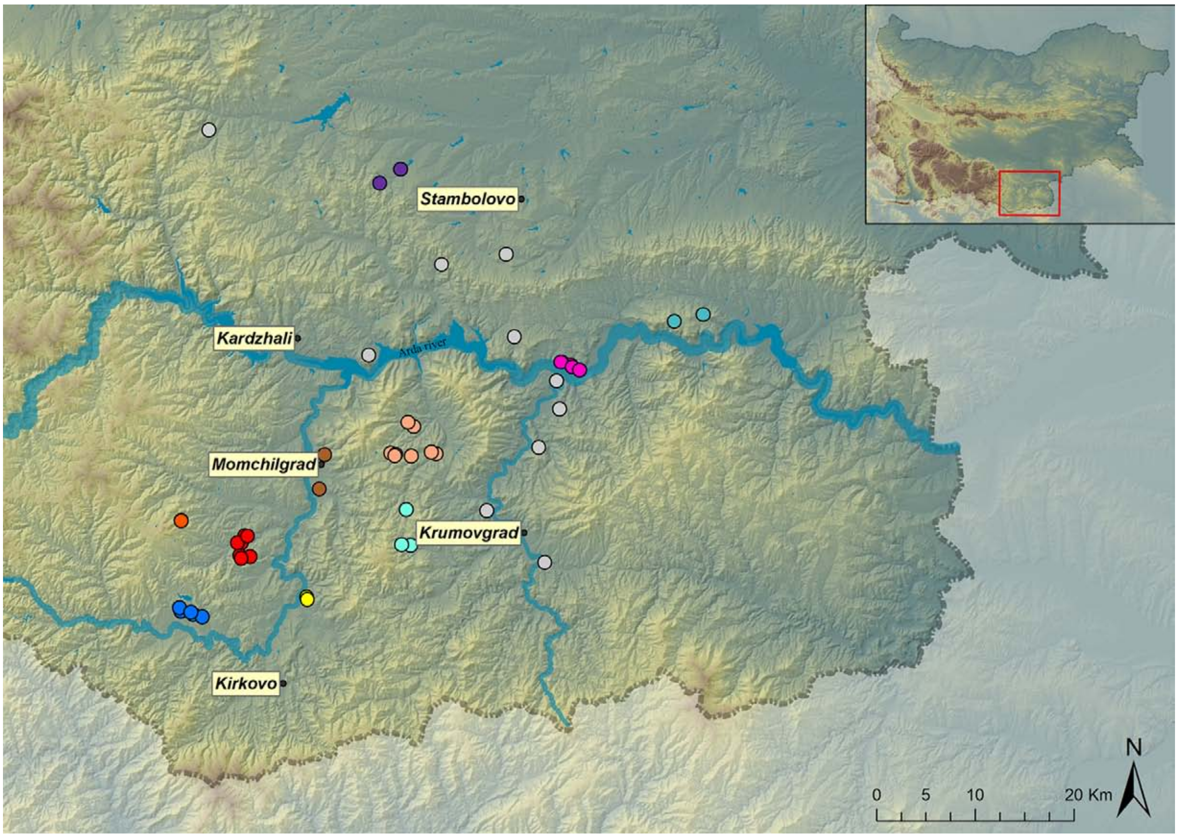

Fig. 4. Map of eastern Rhodope, SE Bulgaria – the black dots mark the towns of Kirkovo, Krumovgrad, Momchilgrad, Kardzhali and Stambolovo. Rivers are marked with blue lines. Presented clusters of rock-cut tombs are marked with dots, each highlighted in a different color. Starting from the southwest and extending towards the northwest: cluster with 5 rock-cut tombs (blue dots), cluster with 2 rock-cut tombs (orange dots), cluster with 8 rock-cut tombs (red dots), cluster with 2 rock-cut tombs (yellow dots), cluster with 2 rock-cut tombs (brown dots), cluster with 3 rock-cut tombs (cyan dots), cluster with 8 rock-cut tombs (green dots), cluster with 10 rock-cut tombs (pink dots), cluster with 2 rock-cut tombs (purple dots). The light grey dots are Single rock tombs that are not in a cluster. Background map: SRTM DEM (USGS. Earth Explorer 2021) (figure by V. Gencheva)

Обр. 4. Карта на Източни Родопи, Югоизточна България с градовете Кирково, Крумовград, Момчилград, Кърджали и Стамболово (черни точки). Реките са маркирани със сини линии. Представените групи от скални гробници са маркирани с разноцветни точки. Започвайки от югозапад и разширявайки се към северозапад: клъстер с 5 скални гробници (сини точки), клъстер с 2 скални гробници (оранжеви точки), клъстер с 8 скални гробници (червени точки), клъстер с 2 скални изсечени гробници (жълти точки), клъстер с 2 изсечени в скали гробници (кафяви точки), клъстер с 3 изсечени в скали гробници (цианови точки), клъстер с 8 изсечени в скали гробници (зелени точки), клъстер с 10 изсечени в скали гробници (розови точки), група с 2 скални гробници (лилави точки). Скалните гробници, които не са в клъстер, са светлосиви точки. Фонова карта: SRTM DEM (USGS. Earth Explorer 2021) (автор В. Генчева)

are often difficult to cross and therefore act as natural barriers that can affect the movement and settlement patterns of human populations.

The result of the query shows that there are 10 distinct groups of points arranged from southwest to northeast. The rock-cut tombs are located mainly in the eastern part of the eastern Rhodope region, in the valley of the Arda River. Only several tombs are situated on the river's left bank, and most of them are on the right. This grouping of points into distinct clusters most likely represents different necropolises. The identification of these clusters and their associated geological forma-

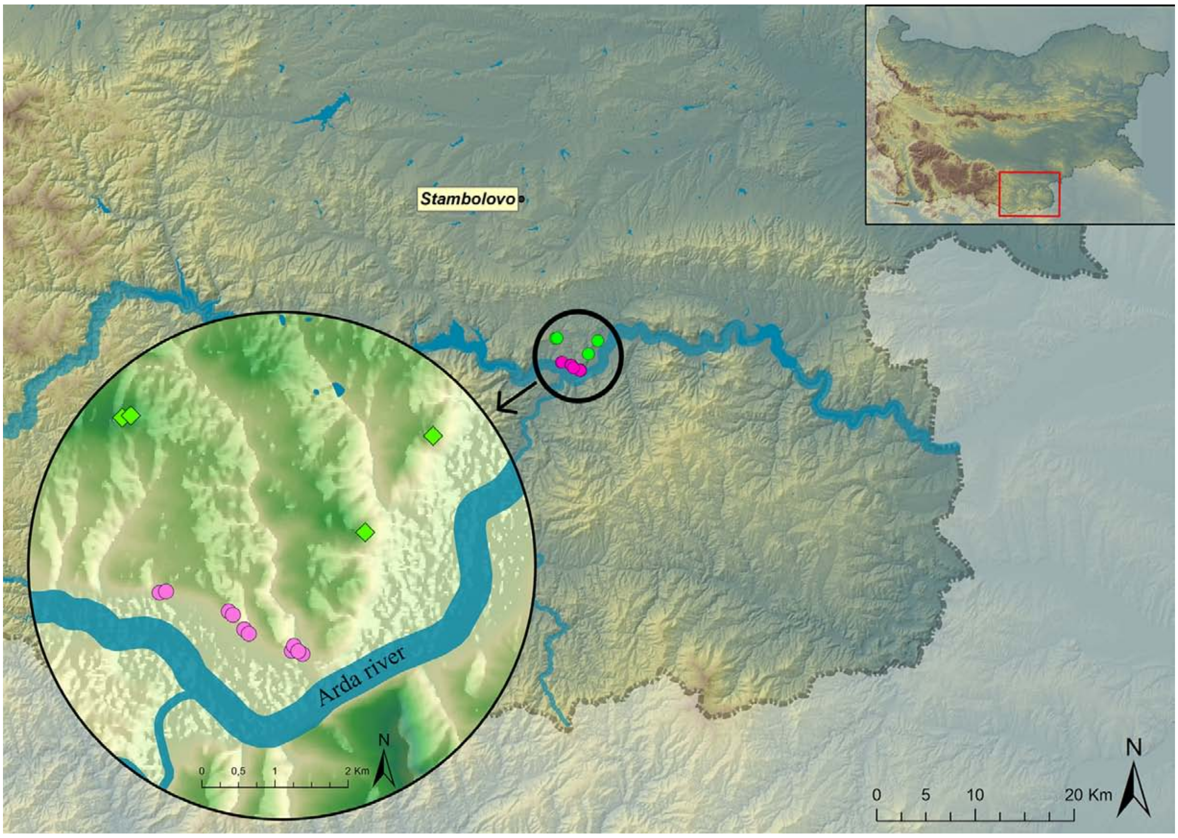

Fig. 5. Map of eastern Rhodope, SE Bulgaria with the town of Stambolovo (black dot). Rivers are marked with blue lines. Clusters with 10 rock-cut tombs are marked with pink dots. The four nearest archaeological sites recorded as settlements from the Early Iron Age are marked with the green dots. Background map: hillshade derived from SRTM DEM (figure by V. Gencheva)

Обр. 5. Карта на Източни Родопи, Югоизточна България с град Стамболово (черна точка). Реките са маркирани със сини линии. Клъстер с 10 скални гробници е маркиран с розови точки. Със зелени точки са отбелязани четири най-близки археологически обекти, регистрирани като селища от ранната желязна епоха. Фонова карта: сянката на хълма, получена от SRTM DEM (автор В. Генчева)

tions raises interesting possibilities for further investigation. One such research would be to identify whether these necropolises also belonged to different settlements. The choice of the cluster or necropolis to apply this query is strongly influenced by the chronology of the rock-cut tombs. Given the absence of dating materials in most of them, a cluster that includes the rock-cut tomb near the village of Pchelari was selected as it provides evidence supporting their dating into the Early Iron Age (Nekhrizov 1994). Ten rock-cut tombs are registered in this micro-region (the area of Dolno Cherkovishte and Pchelari) on the left side of the Arda river (Nekhrizov 2015, 135). This can be achieved by using a spatial 'Nearest Neighbor' analysis with consideration of Arda River in the relational database, which allows the identification of the spatial relationships between different geographic features or objects. By measuring the Euclidean distance between objects and determining which objects are closest to one another, it may be possible to identify any patterns in the placement of these sites in relation to one another.

The analysis resulted in identifying the four closest settlements (fig. 5), all of which are recorded as Early Iron Age settlements. The distance from the centre of the necropolis to each of these settlements was calculated. The nearest site is located 2080 m away, followed by the second nearest site at 3325 m distance, the third nearest site at 3358 m, and the fourth nearest site at 3660. Further analysis will include terrain accessibility, which will be evaluated using DEM files, as an additional factor.

The presented examples show the potential for conducting spatial analyses within a relational database with spatial extension. The findings demonstrate how the integration of diverse sources of data can enable archaeologists to explore complex spatial relationships and gain new insights into settlement patterns, land use practices, and other aspects of the past. It is important to note that further research and analysis using a range of methods and techniques is necessary to fully understand the complexities of the archaeological record.

Expanding on the potential for further analysis using a relational database could be the application of spatial statistics to assess the degree of probability that these settlements and necropolises belonged to the same population in the past. Using site catchment analysis to study the area surrounding an archaeological site can determine the resources that would have been available to its inhabitants. Least-cost path analysis can identify the most efficient routes of movement between sites based on the terrain and other factors such as water sources, food availability, and potential obstacles. The results could include the identification of trade and communication routes and infer information about the economic and political relationships between ancient societies.

These are just a few examples of the many spatial analyses that can be conducted in archaeological relational databases to gain insights into past settlement patterns, land use practices, and cultural behaviours. They demonstrate how a relational database can provide a powerful tool for archaeological research, allowing for more complex and comprehensive analyses of both spatial and non-spatial data.

Conclusion

This paper highlights the advantages of using relational databases in archaeological research. It presents the design and implementation of a relational database with spatial reference to manage and analyse complex archaeological datasets from the eastern Rhodope region in Bulgaria. The potential of relational databases in integrating and managing diverse data sources of archaeological data is demonstrated. It also addresses the unique challenges faced by archaeologists in representing spatial relationships and accounting for multiple scales of analysis.

The main advantage of the designed eastern Rhodope relational database with spatial extension is the organization of spatial and non-spatial data vector and raster data interconnected with each other and thus providing a foundation for ongoing research and interpretation. Managing diverse spatial and non-spatial data simultaneously without proper structuring of the data can be challenging and may lead to inaccuracies. Thus, having clear data structure is of vital necessity.

The relational database in archaeological research provides a powerful tool for integrating and managing diverse data sources. The ability to perform spatial analysis within relational databases leads to new insights and discoveries in the field of archaeology.

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От събиране на данни към анализ: проектиране на релационна база данни за археологически проучвания в района на Източните Родопи

Вероника Генчева

(резюме)

Тази статия има за цел да представи потенциала на релационните бази данни с пространствена референция за археологически цели. Целта на това изследване е да проучи как археолозите могат да подобрят своя анализ на сложни набори от данни чрез изготвяне на релационна база данни, която позволява ефективна организация и интеграция на данни от различни източници. Изведени са основите принципи при проектирането и имплементирането на такъв тип база данни. Дискутира се как употребата ѝ може да улесни проучването на ландшафта и неговата дългосрочна история на заселване. В същото време е обърнато внимание и на предизвикателствата свързани с изграждането на релационна база данни, с интегрирането на данни от множество източници и със създаването на пространствени връзки между отделните данни.

В статията е представена релационната база данни за района на Източните Родопи в България, с по-нататъшната цел да се изследват моделите на заселване чрез идентифициране, картографиране и анализ на археологически обекти и техните пространствени връзки. Тя позволява съхранение, търсене и анализиране на различни типове данни. Такива могат да бъдат археологически обекти (в широк хронологически обхват), данни за околната среда, данни за природните ресурси и изображения представящи явления от реалния свят (стари аерофото изображения, лидар данни, дититален модел на релефа и вторични данни от дигиталния модел на релефа). Данните са дефинирани в геометрично пространство, като вектори и растери. Описаната база данни използва пространствено разширение, което позволява достъп до ГИС програми, което увеличава нейната полза за археологически проучвания. Самата база данни е изготвена с помощта на PostgreSQL и PostGIS разширение.