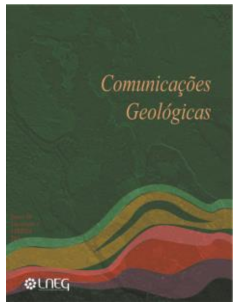
Comunicações Geológicas

Versão online: http://www.lneg.pt/iedt/unidades/16/paginas/26/30/208

Comunicações Geológicas (2015) 102, 1, 79-82
ISSN: 0873-948X; **e-ISSN:** 1647-581X

A spatial data warehouse to predict lithic sources of tombs from South of Portugal: mixing geochemistry, petrology, cartography and archaeology in spatial analysis



Um armazém de dados espaciais para prever as fontes de materiais líticos do Sul de Portugal: combinando geoquímica, petrologia, cartografia e arqueologia em análise espacial

P. Nogueira[1*], P. Moita[2], R. Boaventura[3], J. Pedro[4], J. Máximo[1], L. Almeida[1], S. Machado[5], R. Mataloto[6], A. Pereira[7], S. Ribeiro[8], J. F. Santos[8]

Artigo original
Original article

Resumo: MEGAGEO - Moving megaliths in the Neolithic is a project that intends to find the provenience of lithic materials in the construction of tombs. A multidisciplinary approach is carried out, with researchers from several of the knowledge fields involved. This work presents a spatial data warehouse specially developed for this project that comprises information from national archaeological databases, geographic and geological information and new geochemical and petrographic data obtained during the project. The use of the spatial data warehouse proved to be essential in the data analysis phase of the project. The Redondo Area is presented as a case study for the application of the spatial data warehouse to analyze the relations between geochemistry, geology and the tombs in this area.

Palavras-chave: Geographic Information Systems, spatial data warehouse, Archaeometry, tombs, Portugal.

Abstract: O projeto Megageo tem como objetivo encontrar a proveniência dos materiais líticos utilizados na construção de sepulcros. Nesse sentido foi constituída uma equipa multidisciplinar, com investigadores das diferentes áreas de conhecimento envolvidas. Neste trabalho é apresentado um armazém de dados espaciais criado especialmente para este projeto, constituído por informação dos arquivos arqueológicos nacionais, cartografia geológica e informação geográfica a diferentes escalas, assim como novos dados geoquímicos e petrográficos obtidos durante o projeto. A área de estudo do Redondo é apresentada como um caso de estudo, da aplicação do armazém de dados espaciais e com ele são analisadas as relações entre a geoquímica, a geologia e os sepulcros presentes nesta área.

Keywords: Sistemas de Informação Geográfica, armazém de dados espaciais, Arqueometria, sepulcros, Portugal.

[1]Departamento de Geociências; Escola de Ciências e Tecnologia, Universidade de Évora. Largo Colegiais 2. 7000-803 Évora, Portugal.
[2]Laboratório HERCULES; Instituto de Investigação e Formação Avançada e Departamento de Geociências; Escola de Ciências e Tecnologia, Universidade de Évora. Largo Colegiais 2. 7000-803 Évora, Portugal.
[3]UNIARQ; Faculdade de Letras; Universidade de Lisboa; Município de Odivelas. Alameda da Universidade. 1600-214 Lisboa, Portugal.
[4]ICT; Instituto de Investigação e Formação Avançada; Departamento de Geociências, Escola de Ciências e Tecnologia, Universidade de Évora. Largo Colegiais 2. 7000-803 Évora, Portugal
[5]Laboratório Nacional de Energia e Geologia, LNEG, Estrada da Portela, Bairro do Zambujal, Alfragide, Apartado 7583, 2610-999 Amadora Portugal.
[6]UNIARQ; Faculdade de Letras, Universidade de Lisboa; Município do Redondo. Alameda da Universidade. 1600-214 Lisboa, Portugal.
[7]UNIARQ; Faculdade de Letras, Universidade de Lisboa. Alameda da Universidade. 1600-214 Lisboa, Portugal.
[8]GeoBiotec; Departamento de Geociências, Universidade de Aveiro. Campus de Santiago. 3810-193 Aveiro, Portugal.
*Autor correspondente/Corresponding author: pmn@uevora.pt

1. Introduction

Solving the linkage between the lithic constituents of tombs and the rock outcrops is a problem that has not been extensively addressed in the literature (Andrefsky, 1994; Clarkson and Bellas, 2014). The project “MEGAGEO: Moving megaliths in the Neolithic" gathered a multidisciplinary team, including geologists and archaeologists in a new approach to address this issue.

Based on a database of tombs from Portugal, a set of three study areas was chosen to conduct detailed analyses aiming to identify and characterize outcrops and quarries that might have been the source of the lithic components used in the construction of the tombs. Figure 1 displays the studied areas named Monforte, Redondo and Lisboa after the main localities in their vicinities.

Geological studies included detailed mapping, petrographic and geochemical analysis of samples from outcrops, quarries and tombs to fully characterize each area. A geographic information system was designed and implemented to visualize the collected data and to produce field maps. In the phase of data analysis the spatial information gathered was consolidated and transformed into a spatial data warehouse. This approach is being proposed by many researchers and institutions as can be seen in Bedard and Han (2009), Stefanovic (1997) or McHugh (2008). In this paper we present the results of this approach, using the geochemical results obtained in the Redondo area as a case study.

2. The data sources

The geographic information system created uses several data sources where spatial information (e.g. tomb location or sample location) coexist with non-spatial information (*e.g.* SiO_2 content of a sample or geological description of an outcrop).

For this project a total of twenty two databases were adapted or newly created. These databases include geographic information (*e.g.* roads, rivers, terrain slope, localities), geological information, such as geological mapping at scales 1:50 000, 1:500 000 and 1:1 000 000, including rock formations and structures, archaeological information (*e.g.* location and types of tombs, tomb description, site sketch), and petrographic and geochemical data from samples collected in tombs and outcrops. Figure 2 shows the general organization of the GIS database system created.

This data organization proved to be valuable in the phase of field campaigns and data collection as it was possible to rapidly produce maps to support field work and some synthesis maps needed when presenting the results in conferences (*e.g.* Boaventura *et al.*, 2015). Our experience demonstrated that this approach is suitable for a system that is operated by GIS-specialists but whenever it is necessary to carry out data analysis from the point of view of non GIS-specialists, the complexity of the data structure becomes difficult to use. The maintenance of such a system is also a time consuming task because data consistency must be kept at all time whenever there are many researchers adding data to the system. In terms of databases terminology the GIS-database system is considered a SOLTP system that is a Spatial Online Transactional Process because the data is handled as a transactional system.

The spatial data warehouse was created to help the researchers of the project with a set of tools that might be usable in data analysis without the need to spend considerable amounts of time understanding all the operations and terminology specific to GIS systems. This approach implies the passage from a SOLTP to a more analytical system, that is, a Spatial Online Analytical Process, a SOLAP (Kimball and Ross, 2002; Bedard and Han, 2009).

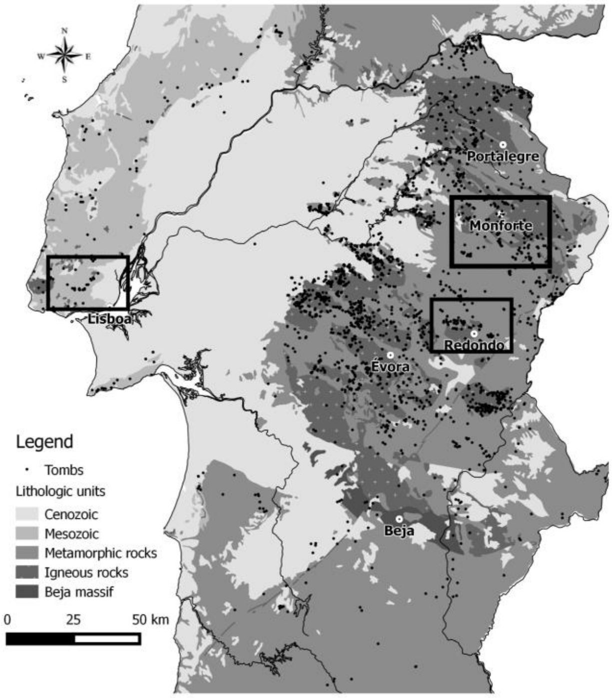


Fig. 1. The study areas of the Megageo project.

Fig. 1. As áreas de estudo do projeto Megageo.

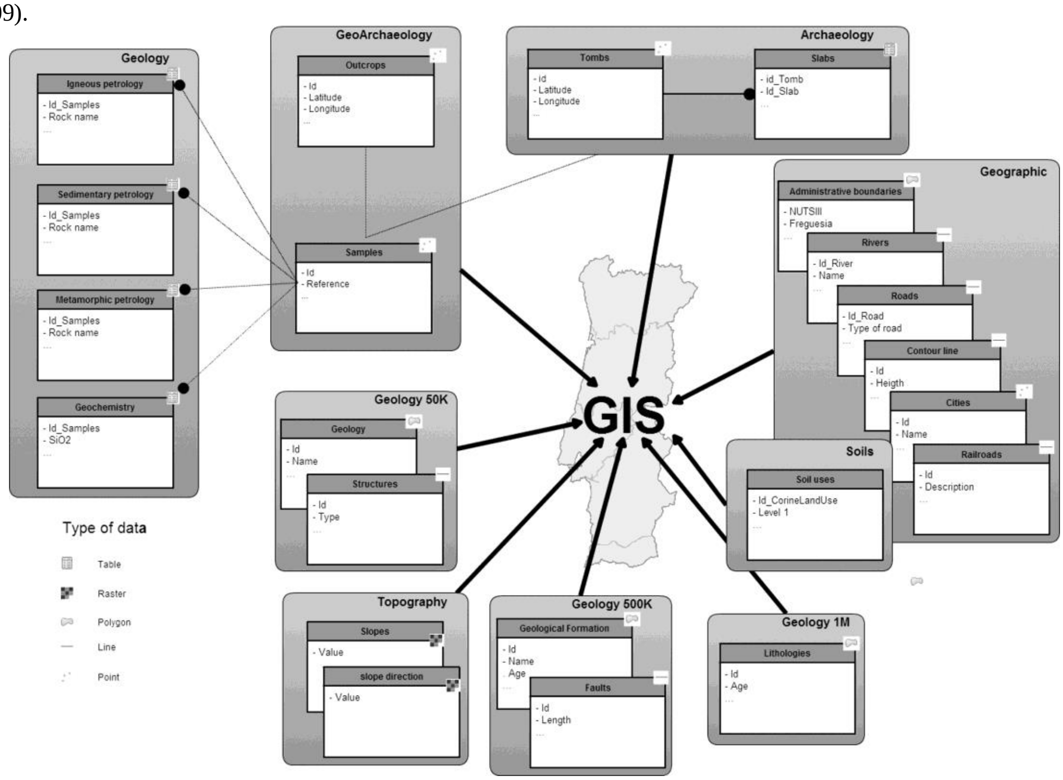


Fig. 2. The databases used in the geographic information system created.

Fig. 2. As bases de dados utilizadas no sistema de informação geográfica criado.

3. The Spatial Data Warehouse

Two datamarts were designed to respond to the geologists and the archaeologists questions. The geology datamart has got a fact table that is centered on the samples collected and the dimensions present include the outcrops, the tombs, the geology and the geography. For the archaeology datamart the fact table is centered in the tomb and as dimensions there is the geology, the petrography, the geochemistry and the geography.

McHugh (2008) classified the dimensions of GIS databases as geometric, non-geometric and mixed according to the type of data contained. The transformation of these dimensions from the GIS database to a spatial data warehouse implies a process of Extraction, Transformation and Loading - ETL of information (Harvey and Jiawei, 2009). This ETL process includes several types of operations such as aggregation, filtering, aliasing or geocoding. An example of this is the transformation of chemical weight percentage of elements to a normalized description, allowing the archaeologists to understand the meaning of geochemical data and common names used in its description, aliasing.

The ETL stage is error prone, complex and time consuming as the studied areas include all types of rocks and the interpretation needed for the geochemical and petrographic values and descriptions of sedimentary, metamorphic or igneous rocks is very different. An example is the creation of a set of fields for rock classification according to the geochemical contents of analyzed samples. For example classifying the acidity of a rock is based on the values of SiO_2 leading to common names of mafic, intermediate or felsic. This transformation is made using an expression of the type:

IF((“SIO2”) <= 52, 'MAFIC', IF((“SIO2”)< 63, 'INTERMEDIATE', 'ACID'))*

* QGIS type expression. Field names are between double quotes.

This transformation can only be applied in meaningful terms to igneous rocks, therefore a filtering of these types of rocks is necessary previously to the step of rock classification. Fig. 3 is an example of a map where the samples are classified according to their silica content.

4. The outputs

The Redondo area is presented as a case study of this approach. A set of thirty two dolmens can be found and eight of these were selected for detailed studies in the project. The outcrops of the area were mapped to find the ones that might have produced rock slabs used in the construction of the dolmens: the source rocks.

Figure 3 displays a map constructed in QGIS under the spatial data warehouse created for the project. In this map a buffer with a 250 m radius was displayed confirming that the found outcrops are in an easily reachable distance for rock slab transportation and seven out of eight of the studied dolmens are within this range. Furthermore, this map displays the silica content from the rock slabs and from the outcropping rock type. This analysis demonstrates that there is a good match between outcrop rock type and rock slab silica content. Nevertheless, further analysis needs to be done in the dolmen from the northeast part of the map where the rock slab is of basic composition whereas outcropping rocks are more felsic.

The spatial data warehouse also pretends to be useful for data analysis, therefore, for the data visualization it is necessary to include background map information. This background information, that is predefined, must be prepared including the

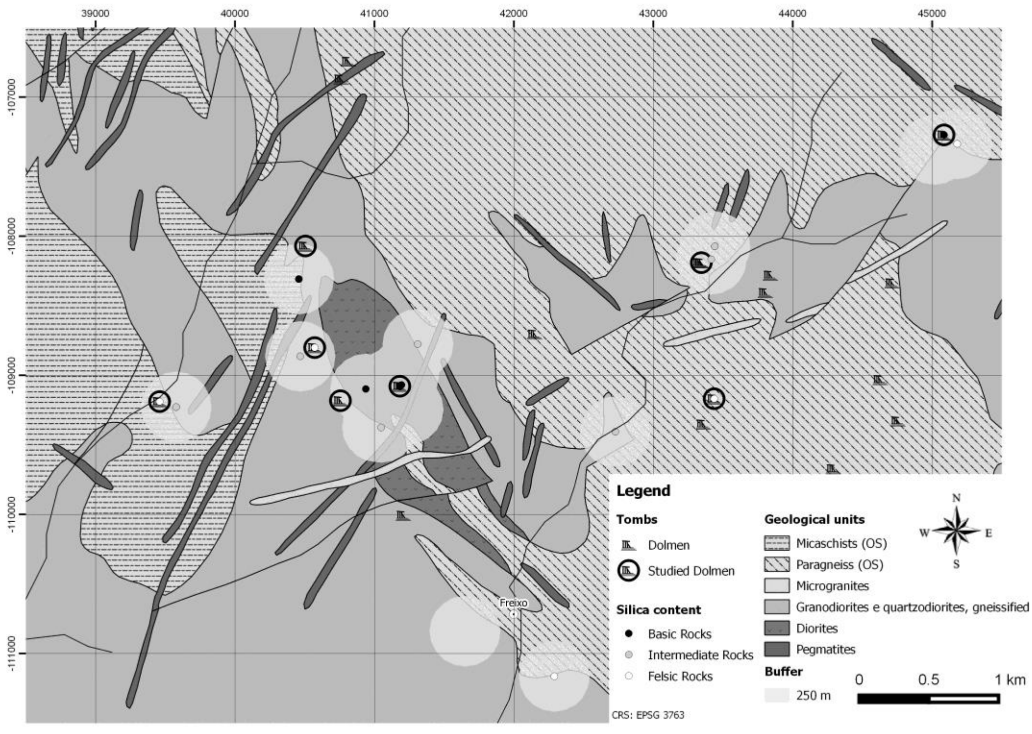


Fig. 3. Example of a map displaying the buffered distance between outcrops and tombs in the Redondo area.

Fig. 3. Exemplo de um mapa onde é mostrada a área a igual distancia entre afloramentos e sepulcros na área do Redondo.

set of legends and labels for specific uses. An example of this is the set of geological maps with the standardized symbols and names of the geological units in Portuguese and English. Also for publishing purposes the different symbols were created in gray shades and in full color.

Another example of a possible analysis done with the spatial data warehouse is the visualization of data based on a set of rules. When the geologists team wants to verify if it is necessary to consider further sampling and analyses of REE and isotopes it is possible to prepare a map were the analyzed samples are plotted and the values displayed in a suitable geological background. Figure 4 illustrates an example of the output map produced for the Redondo study area. In this map a filtering is done to display only the samples analyzed for $^{87}Sr/^{86}Sr$ and La/Lu ratio.

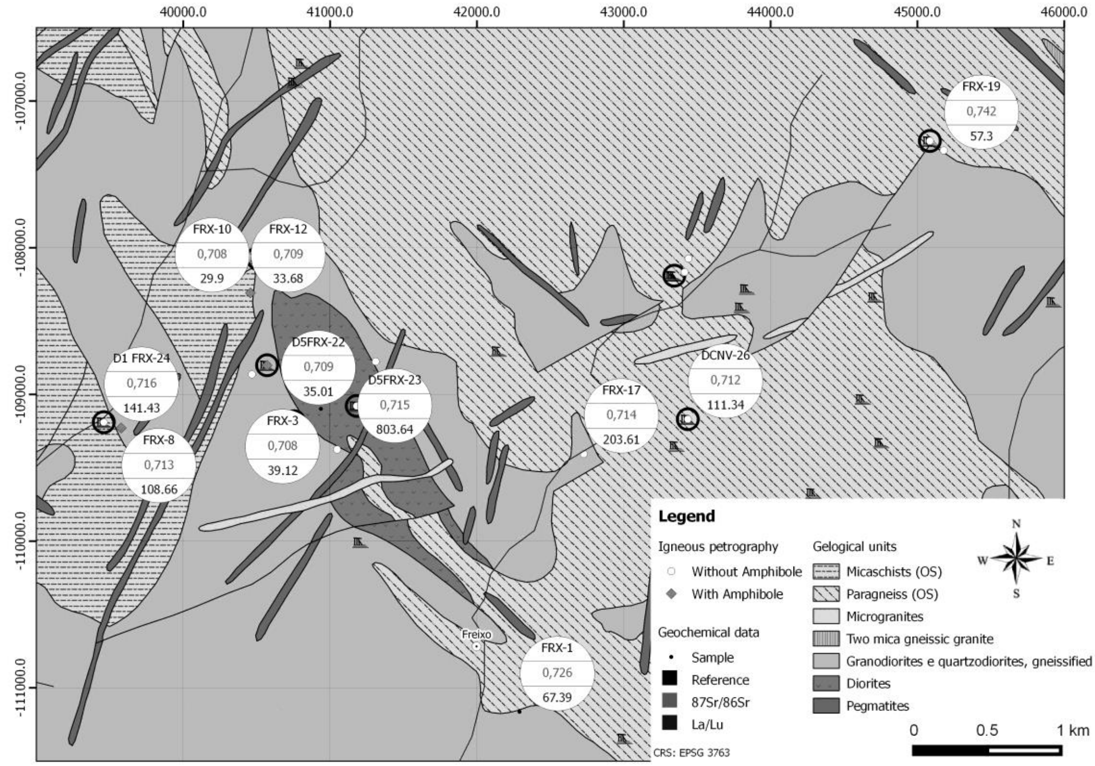


Fig. 4. Example of a map of the Redondo area, displaying the samples analyzed for REE and the ratios of $^{87}Sr/^{86}Sr$ ratio and the La/Lu. Petrographic information on the amphibole presence is displayed as different symbols on the map. This map allows evaluating the relation between geochemistry, petrography and tomb location.

Fig. 4. Exemplo de um mapa da área do Redondo, onde são apresentados as amostras analisadas para terras raras e mostrados os valores das razões $^{87}Sr/^{86}Sr$ e La/Lu. A presença ou ausência de anfíbola é apresentada com símbolos diferentes. Com este mapa é possível avaliar as relações entre geoquímica, petrografia e localização dos sepulcros.

6. Conclusions

In a multidisciplinary project such as the one presented, new tools have to be developed in order to find common means for analyzing and interpreting data.

The spatial data warehouse specially created for the project is being used has a better tool in the analysis of the complex and multidimensional data that is used to find the relation between tomb sites and lithic material sources. The interpretation of the geochemistry and petrology of the samples can be combined with the archaeological information by all the researchers of the project without the need of high skills and knowledge of GIS.

Acknowledgments

This work is part of the project PTDC/EPH-ARQ/3971/2012 funded by the European Fund FEDER and COMPETE – Programa Operacional Fatores de Competitividade (POFC).

References

Andrefsky, W., 1994. The geological occurrence of lithic material and stone tool production strategies. *Geoarchaeology: Int. J.*, **9:** 375-391.

Bédard, Y., Han, J., 2009. *Fundamentals of Spatial Data Warehousing for Geographic Knowledge Discovery*. In: Harvey J. Miller, Jiawei Han (2009). Geographic data mining and knowledge discovery, 2nd edition, CRC Press, 46-67.

Boaventura, R., Moita, P., Pedro, J., Nogueira, P., Machado, S., Mataloto, R., Pereira, A., Máximo, J., and Almeida, L., 2015. Tombs and Geology: Physical constraints and funerary choices during the 4th-3rd-millennia BCE in Central-South Portugal. *Proceedings of Conference: Megaliths, Societies, Landscapes*. *Early Monumentality and Social Differentiation in Neolithic Europe*. Kiel University, 16 - 20 June 2015.

Caldeira, C., 2012. *Data Warehousing. Conceitos e modelos com exemplos práticos*. 2ª Edição. Edições Silabo, 208.

Clarkson, C. and Bellas, A., 2014. Mapping stone: using GIS spatial modelling to predict lithic source zones, *Journal of Archaeological Science*, **46:** 324-333.

Harvey, J., Jiawei, H., 2009. *Geographic data mining and knowledge discovery*, 2nd edition, CRC Press, 461.

Kimball, R. and Ross, M., 2002. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*, 2. Edition, Wiley.

McHugh, R., 2008. *Intégration de la structure matricielle dans les cubes spatiaux*. Msc Thesis, Université de Laval, Québec, 128.

Stefanovic, N., 1997. *Design and implementation of on-line analytical processing (OLAP) of spatial data*. PhD Thesis (School of Computing Science)/Simon Fraser University, 108.