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Glacial and periglacial data integration in a GIS: methodology used in the Serra da Estrela, Portugal

Gonçalo Teles VIEIRA

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The methodology applied in the research in Serra da Estrela (Portugal) is to integrate glacial and periglacial geomorphological data in a Geographical Information System and a Database Management System. The main objective of the procedure is to make use of low cost software for geospatial data integration, statistical analysis and production of geomorphological maps. The digital storage format provides the means for fast access and easy transportation of the data during field campaigns. It is also a very useful way to store the geomorphological data, so it can be used in the future by other researchers working in the area.

Gonçalo Teles Vieira, Centro de Estudos Geográficos, Universidade de Lisboa, Faculdade de Letras, Cidade Universitaria, 1600-214 Lisboa, Portugal; e-mail: gtvieira@ceg.ul.pt (received: August 12, 1999; accepted: September 27, 1999).

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INTRODUCTION

The Serra da Estrela (1,993 m a.s.l.) is a granitic mountain located in the Iberian Cordillera Central (Fig. 1). It is a significant area in the framework of Quaternary science, as it presents the best preserved glacial and periglacial landscape of Portugal. The geographical position of the mountain at 40°20'N and 71°35'W and relatively low altitude make it an important site for palaeogeographical reconstruction in the western European framework. Despite the absence of direct absolute datings, glacial deposits and landforms are attributed to the Last Glacial Maximum (Daveau, 1971; Ferreira, 1998; Vieira and Ferreira, 1998). The more significant periglacial evidences are attributed to the same period, but more recent periglacial events seem to have occurred (Vieira, 1998). Above *ca.* 1,750 m a.s.l., marginal cryogenic processes are active today and play a role in the morphogenesis.

General aspects of the glaciation of the Serra da Estrela were first pointed out by Lautensach in 1932. In the late 60's S. Daveau defined with a good accuracy the glaciation limits and their characteristics (see Daveau, 1971). But until the mid-90's research on glacial and periglacial problems of the Serra da Estrela had almost stopped. The need for better knowledge of glaciation, especially rearding detailed geomorphological mapping, sedimentological study of the deposits and dating, led to a new line of research conducted by investigators from the Physical Geography and Environmental Research Group of the Centro de Estudos Geográficos (University of Lisbon), which started in 1995.

It became clear very early that the data collection generated significant amounts of information that would rapidly become difficult to manage. It was decided to store the data in digital format in order to promote an easy access to information, availability for statistical analysis, visualisation, printing, etc. Furthermore, the use of CD-ROM for data storage should allow high mobility for the whole database (e.g. during fieldwork campaigns).

Taking into account the financial limitations for the research and the lack of personnel it was decided that the software should be affordable and relatively simple to use. Therefore, for the construction and analysis of the cartographic database we use the raster Geographical Information System ILWIS (Integrated Land and Water Information System) and for the final outputs the design package Microstation 95 is employed. The alphanumeric data are stored in a relational data base management system (*cf.* IAEA, 1993). The data transfer between the three packages is relatively simple but not direct. In the future we intend to compile the data in CD-ROM using a current Internet browser as a viewer (Fig. 2).

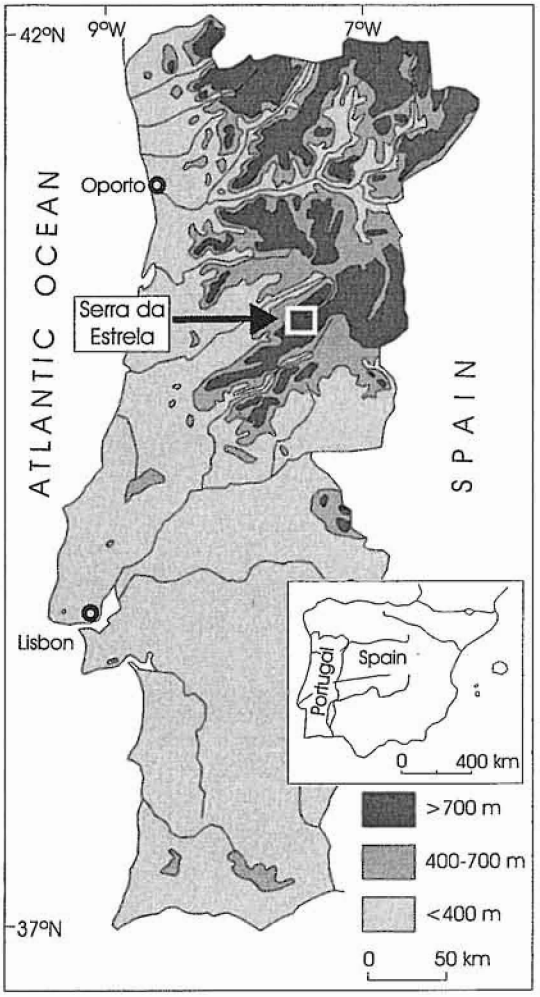

Fig. 1. Location of the Serra da Estrela in Portugal

The examples presented in this paper relate to the geomorphological research carried out in the Zêzere catchment (*ca.* 62 km^2), chosen as the first area to be studied in the Serra da Estrela.

CARTOGRAPHIC DATABASE

The cartographic database incorporates the spatial information and includes point, line and area (polygon and raster) data and attribute tables (Fig. 3). The GIS software that is used allows the direct digitising (via digitising tablet or on-screen, using a pointing device) of cartographic data (Budde *et al.*, 1997; Van Westen and Farifteh, 1997; Van Westen *et al.*, 1997). The data sources are published maps, aerial photographs, orthophotographic maps and field maps. Georeferenced points also can be entered into the database (e.g. exposures of deposits or GPS reference marks). Point, line and polygon data are linked to attribute tables. These types of layers can only be used directly for visualisation purposes; for analytical purposes a raster transformation needs to be performed.

The geomorphological data layers constructed in the GIS are to be exported to Microstation 95 and will be used for the production of detailed geomorphological maps of the study areas.

THE DIGITAL ELEVATION MODEL AND DERIVATIVE LAYERS

The Zêzere catchment Digital Elevation Model (DEM) was constructed from a 10 m contour interval topographic map rasterized using 10 m pixels. This size allows the detailed location of the features in the field and a good spatial resolution for the DEM.

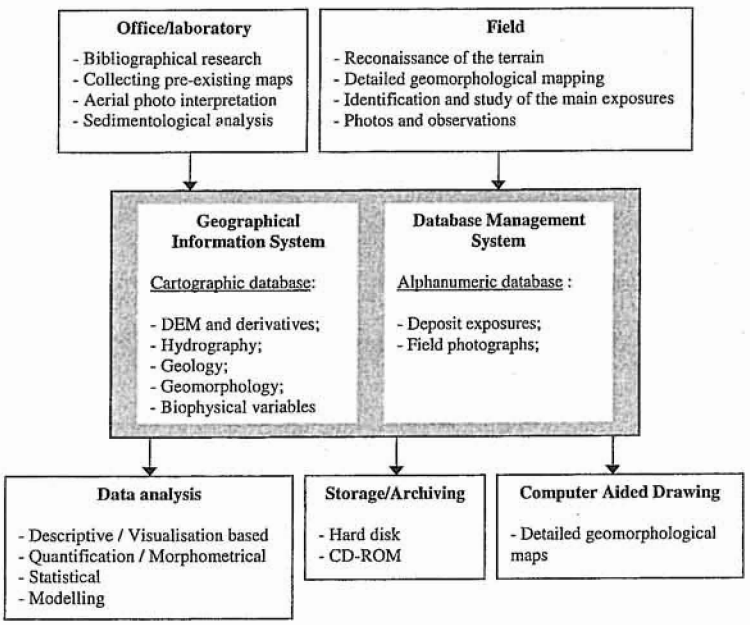

Fig. 2. Methodology used in the Serra da Estrela

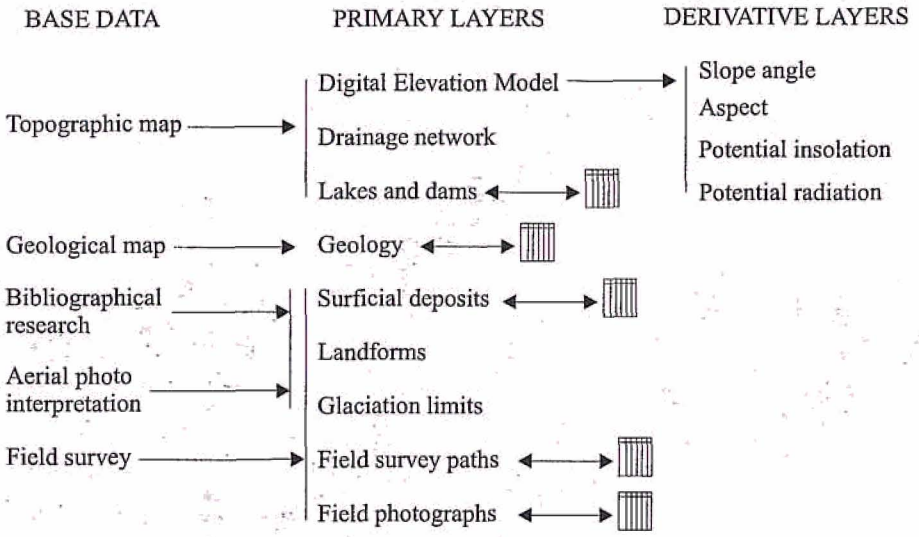

Fig. 3. Cartographic database of the Zêzere catchment

In geospatial analysis, the DEM is one of the most important layers, as it is the base for the elaboration of other topographic derivative layers (e.g. slope and aspect) that are important variables in a geostatistical approach to geomorphological analysis (Fig. 4).

From the DEM it is possible to generate slope angle and aspect maps and with trigonometrical formulae applied using iterations, to calculate a shadow map for a chosen date and hour (Vieira, 1999) and therefore potential radiation maps (Felicísimo, 1994; Meijerink *et al.*, 1994; Vieira, 1999) (Fig. 4).

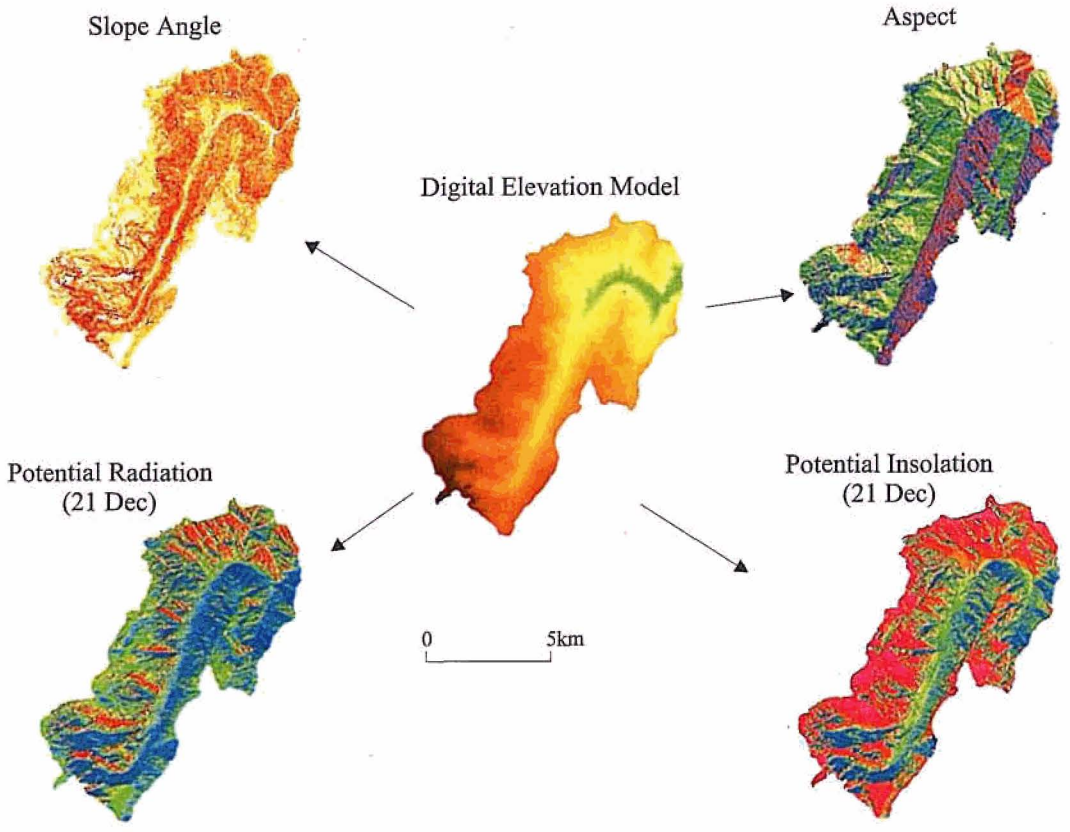

Fig. 4. Digital Elevation Model and some examples of derivative layers constructed for the Zêzere catchment

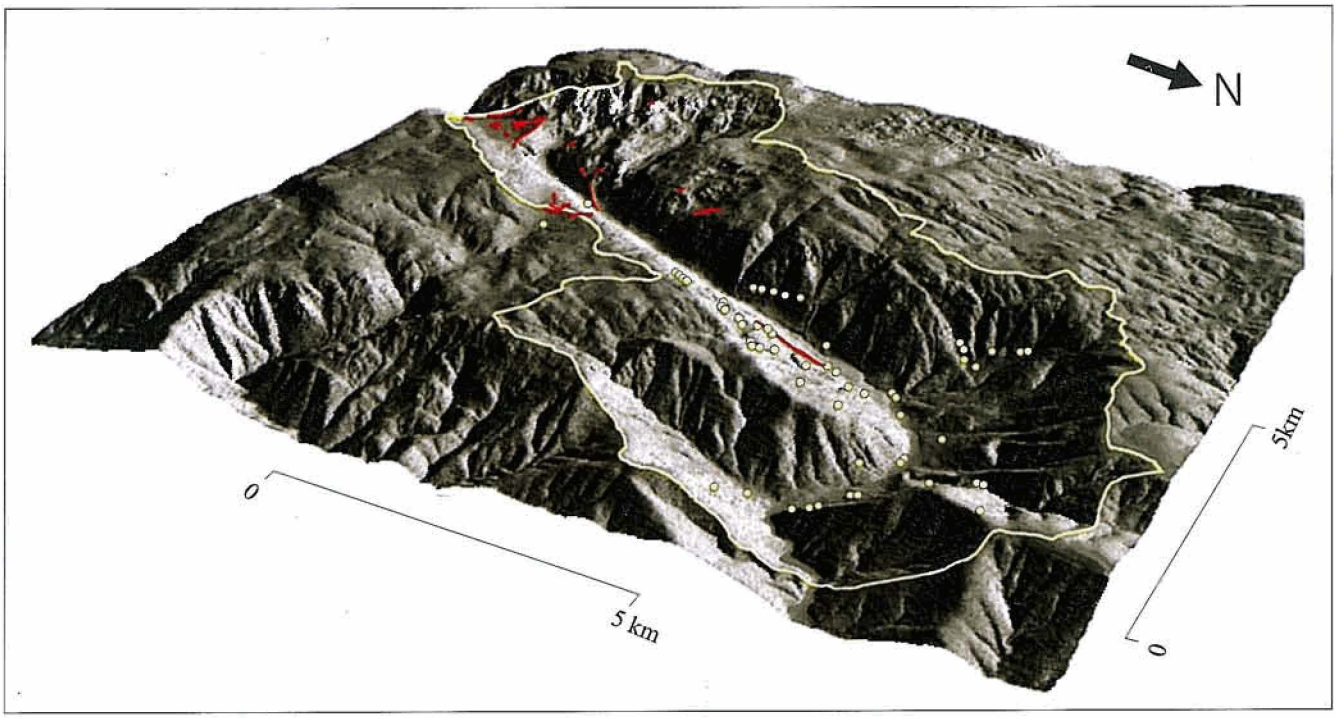

Fig. 5. Display of the Digital Elevation Model of the Zêzere valley with shaded relief as drape file

The Zêzere catchment is marked in yellow, the main moraine ridges in red and the dots represent the exposures of Quaternary deposits

These are especially significant in the study of glacial and periglacial geomorphology.

The DEM can also be used for generation of cross-sections and 3-D visualisation of the landscape, if necessary, using also raster drapes (e.g. geology or location of the moraines — Fig. 5).

Hydrography. Layers with the hydrographical features include the drainage network and the lakes and dams. They were digitised from the 1:25,000 topographic map. The lakes in the Serra da Estrela correspond to old glacier basins and are relict glacial forms. A unique identification was given to each of them, and they are linked to a table used for storage of related information. The drainage network layer serves for performing morphometrical analysis, and useful information can be retrieved from it enabling the location of valley floors and calculations derived from that parameter.

Geology. The geology layer was digitised from the 1:50,000 geological map of the area and represents the substratum. Surface deposits were digitised in a separate layer and were mapped directly in the field. The geology layer is originally a polygon layer connected to a table where the main characteristics of the geological formations are included. Whenever an analysis is to be done, a raster layer with the chosen lithological attribute must be produced (e.g. texture, lithological type).

Geomorphology. The construction of the layers on the geomorphological variables is one of the main objectives of the study that is being carried out in the Zêzere valley. The data are in fact a result of the research in the area and therefore their integration proceeds as new field data become available.

The geomorphological layers include the surficial deposits and the landforms layer. They were constructed using field observations and aerial photo interpretation and their purpose is to serve both for visualisation and geostatistical analysis. Exposures of deposits are represented in a point map with unique identifiers for each deposit and linked to a table that allows logging their geographical and sedimentological characteristics. The unique identifier allows fast access to the alphanumeric database of the deposits, which includes photographs and sketches of the exposures.

ALPHANUMERIC DATABASE

The alphanumeric database includes the georeferenced point data representing the exposures of deposits and pictures taken during field work. It serves both for archive and analysis purposes and can be exported to the GIS package.

The exposures database is an exhaustive record of the exposures in Quaternary deposits and holds photographs and other significant sedimentological and interpretative data (Fig. 6). The data can be used for statistical analysis and cartographic representation. It is a valuable resource for future research in the area and also for landscape planning issues in the framework of the Serra da Estrela Natural Park, as it allows for rapid identification of the more significant deposits and of their characteristics.

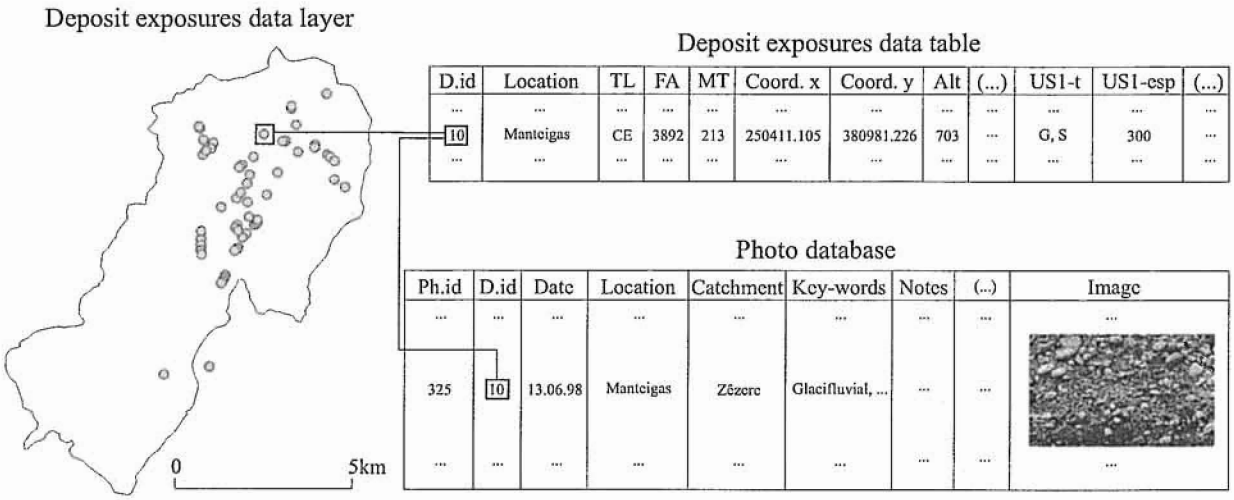

Fig. 6. Organisation of the deposit exposures data in the GIS and DBMS (please note that the survey of the exposures in not yet complete)

The photographs database includes all the pictures (and observations on their characteristics) made during field work. The digital format of the data makes it especially easy for transportation and therefore to be carried in field campaigns. In this way, it is possible to visualise older photos and notes.

CONCLUSIONS

The integration of the glacial and periglacial data of the Serra da Estrela in a GIS constitutes an excellent way for storage of the data captured and produced during research projects in the area. This data is easy to retrieve and use, both for visualisation and analytical procedures.

Expected uses for the database include the support for research conducted by investigators of the Centro de Estudos Geográficos and by students of the Department of Geography of the University of Lisbon. A project with the Natural Park of the Serra da Estrela is expected in order to promote the use of the database as a tool for planning purposes, especially in what concerns to the conservation of the geomorphological assets of glacial and periglacial origin.

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