DATABASES FOR GEOLOGICAL MAPS WITH THE USE OF GIS OPEN SOURCE SOLUTIONS

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Abstract

The Geographic Information Systems (GIS) are widely used for the administration, visualization and spatial analysis of the geographical type of information. The geological maps represent an important field for the GIS technology applications and there is a large number of commercial or open source applications. The open source solutions are more and more used as an alternative for completing the commercial applications. Thus, the geological map is presented as a relational type database, using PostgreSQL with the PostGIS extension. The symbolization and visualization operations are performed with GIS desktop applications (Quantum GIS, GvSIG).

Key words: GIS, geological maps, geodatabase, PostGIS.

Introduction

The open source type of GIS software packages experienced a popularity growth in the geoinformatics field, given the fact that its licenses provide freedom of utilization, redistribution and modification. These play an important role in overcoming the barriers imposed by the costs of the utilization of GIS instruments, thus developing as an alternative solution for the owners of GIS software.

This paper illustrates the application of open source GIS solutions in order to execute the Saru Dornei map sheet database, on a 1:50.000 scale, as a template for the continuation of the following sheets. The geospatial database execution and the displaying as geological maps, in different forms, in comparison even with an established commercial solution, will be demonstrated.

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The open source GIS solutions provide the possibility of collecting, administrating, processing, interpretating and displaying geospatial data instruments. These can be divided into server products and desktop products. If compared to established commercial products, these have different limitations, depending on the specific field of utilization. The more they are developed, the more the number of limitations decreases, facilitating their progressive utilization. The study of open source capacities has demonstrated the possibility of implementing them on different operating systems, some of which are free of charge, the capacity to connect to geospatial databases, the reading of different file formats, conversion possibilities of data to different formats or topographic projections, the possibility to execute or utilize supplementary modules, vector or raster data analysis possibilities, three-dimensional representations, geostatistical analysis, etc.

Database creation (Geodatabase)

1. Geodatabase analysis and design
The information source is formed by the geological map sheets, which can be printed maps, transparent tracing paper layouts used by publishing house or original working maps. By means of geological map constitution analysis, there can be figured out a series of elements to be separated into feature classes, feature datasets:
- limits of geological units (normal or unconformable), contacts of eruptive rocks, lithological changes, etc;
- faults, able to shift the geological limits;
- geological limits, limited by geological limits or faults;
- rock levels with linear representation (limestones, amphibolites, etc);
- observation points, which can contain descriptions or measurements (structural, geochemical, geophysical);
- topographic elements: rivers, contour lines, localities, lakes, roads, etc.

In the cartographic representation of maps, associated elements are used (legends, geological sections, lithostratigraphic sections, tectonic drafts, data source drafts). All these are formed of lines, polygons, points and texts, which will be taken over as separate sets of data and represented in the map printing format.

As an essential stage, the geodatabase design comprises, following the data analysis, the realization of three standard stages:
- the conceptual model – the abstract representation of data in order to identify relations and components;
- the logical model, more detailed and closer to the RDBMS level, includes the entities attributes and the relations between them;
- the physical model, the most detailed, executed in a tight connection with the system which will be used to implement the database.

The logical model of the database (fig. 1) is being executed on the basis of the established elements in the conceptual model, including tables, attributes and relations, using their names and organization from the database. Practically, the disposing of these

elements is independent from the platform, it constitutes the basic element onto which the physical database will be. For the 1:50.000 scale map sheets, there can be created a database (geodatabase) for each sheet, with the name given by the sheet indicative. The entities (the layers containing geospatial objects) of a geodatabase are grouped in feature datasets, accordingly figured in the chart (Geology, Basemap and Legend).
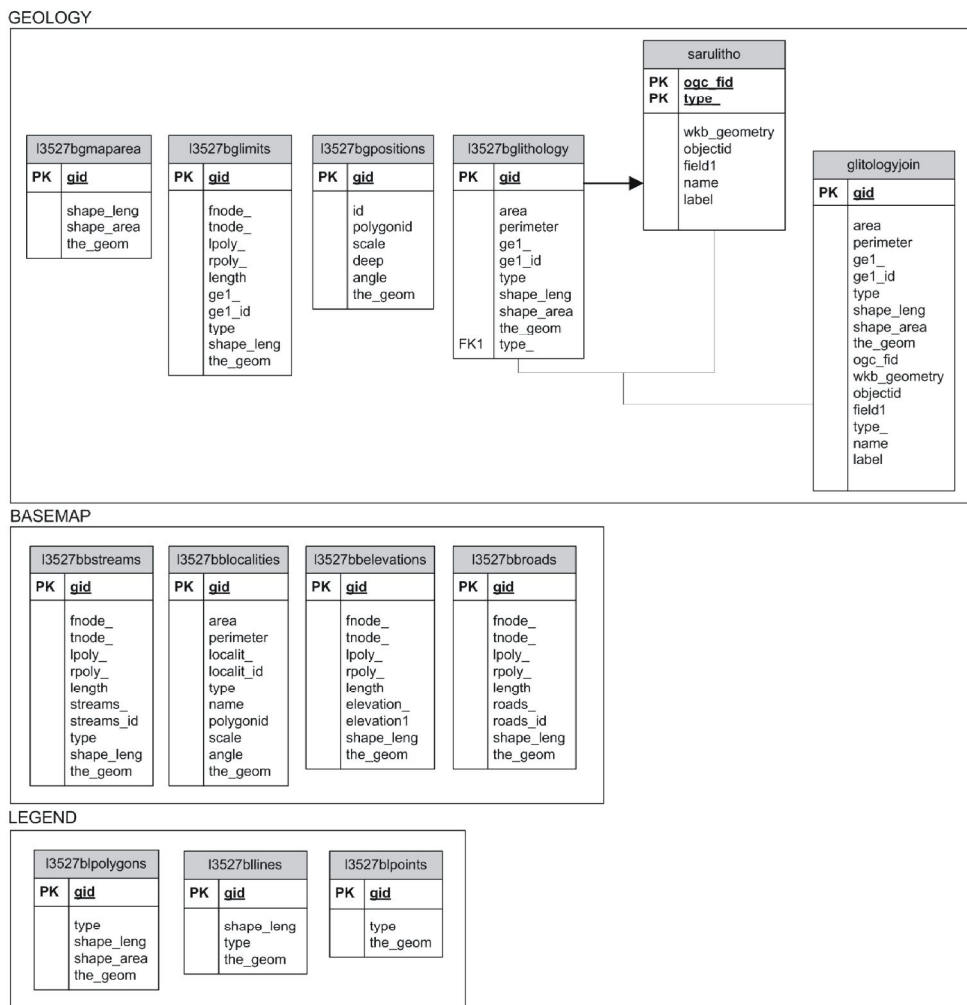

Fig. 1 The database logical model for the geological maps

The tables of attributes (dictionary) comprise the elements used for the symbolization and labeling of the objects which are 1 – m related to the main entities with the spatial data, thus performing a normalization, which determine the information to be stocked one time only. In order to ease the scaling of the personal database to an enterprise database, a table

naming convention has been performed on a GIS server: the entity name has as a prefix the sheet indicative, followed by the first letter of the name of the feature dataset it is a part of.

All the entities comprise the following common fields: the primary key, the geometry field, type (classification) of data (external key in 1-m relation with the dictionary tables).

Within the last years, geospatial data is stocked in databases containing a spatial extension, through which these are being adapted to stock specific spatial information (geometry) and the associated attributes. PostgreSQL is a free of charge database system, launched under BSD license, developed by a globally widespread community and by a number of companies. PostGIS is an open source extension, which adds spatial data support to the PstgreSQL system. It follows the OGC (Open Geospatial Consortium, Features for SQL) specifications, including geometrical types (point, line, polygon, multi-line, multi-polygon), operators for spatial measurements, operators for spatial operations, indexing support for performance growth.
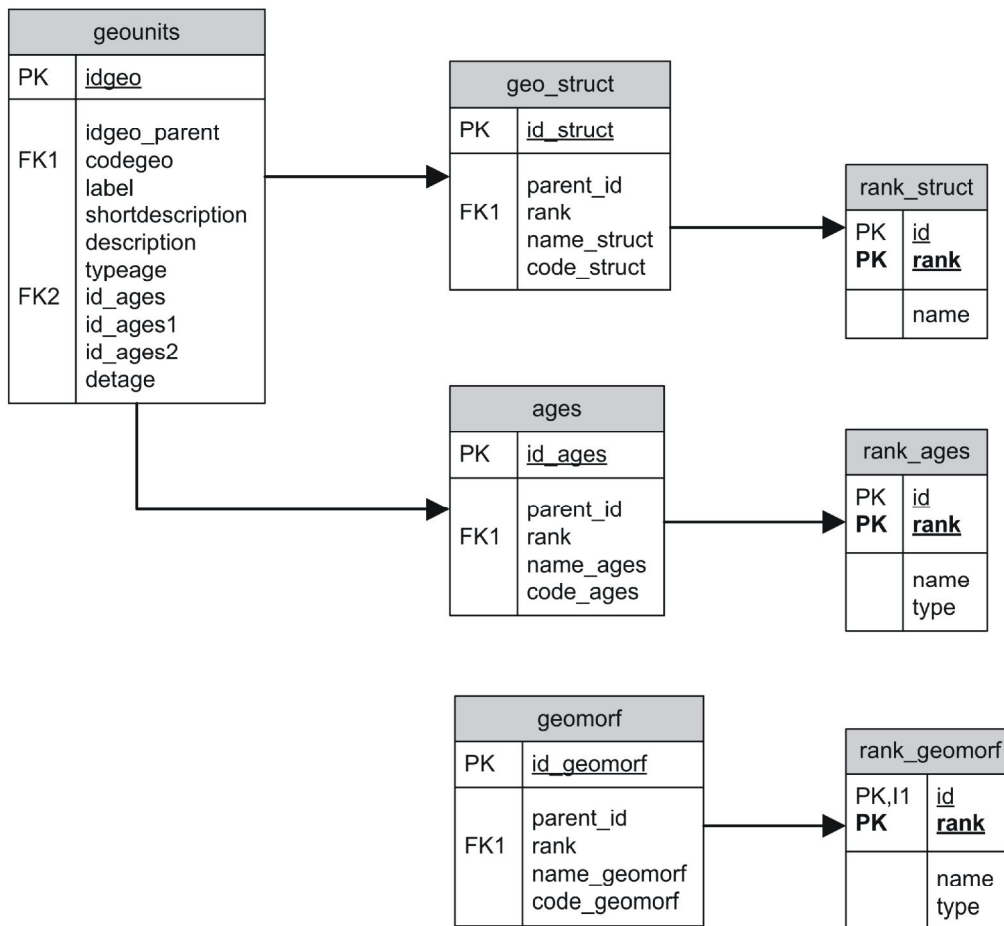
Fig. 2 – Sample of dictionaries structures with geological concepts or classifications

A specific ArcGIS (software GIS made by ESRI) feature is the possibility to create elements which would help administer the database: the geodatabase creation and the stocking of data into the database, the feature datasets, the entities with feature datasets, the tables with attribute data, relations between entities and tables, subtypes of an attribute, variation fields of an attribute, rules of spatial element topology. The geodatabase term, introduced by ESRI (Environmental Systems Research Institute) and used by ArcGIS, may be extended also for the PostgreSQL/PostGIS solution, with the following correspondences:
- geodatabase – database instance;
- feature dataset – scheme;
- feature class – table.

Depending on the real data, the layers (tables) were separated and grouped in layouts:
- geology with tables l3527bglithology, l3527gblimits, l3527bgpositions, l3527bgmaparea;
- basemap with tables l3527bbstreams, l3527bblakes, l3527bbelevations, l3527bblocalities, l3527bbpoints;
- legend with tables l3527blpoints, l3527bllines, l3527blpolygons, l3527bltexts.

The dictionaries represent attribute sets (tables) connected to the spatial objects by means of a key (field). In the geological database, there can be created dictionaries having the necessary attributes for geological map representation and symbolization, as well as dictionaries with geological concept classification (fig. 2). The dictionaries belonging to the first category are in a 1 – m relation with the spatial data layers, connected by means of the key field „type". They generally contain the object id, type, name, label, description, style fields and are used especially when symbolizing spacial elements and stocking the associated labels, being, basically, the geological legend base.

2. Data acquisition and administration

The geospatial data stocked within a relational database can be administrated by means of direct access of the database or by means of GIS desktop applications. There are several GIS open source applications, which can be connected to PostgreSQL/PostGIS: GRASS, Quantum GIS, gvSIG, Mapwindow, Jump, Udig. The last vaersions of Quantum GIS and GvSIG applications have been selected for utilization.

Quantum GIS is an independent project, launched in 2002, which is able to use the GRASS functionality through a plug-in. Here are the main functionalities and characteristics:
- easy installation and rolling on several platforms;
- PostgreSQL/PostGIS database accessing;
- accessing of several vector, raster, WMS, etc. formats;
- projecting of vector information;
- displaying the attribute database;
- symbols administration;
- maps' layout;
- export to Mapserver format;

‒ spatial data simple analyses;
‒ extension through a system of plug-ins.

GVSIG is developed by the Regional Ministry of Infrastructure and Transports (Valencia – Spain) and is part of a wider migration strategy to open source solutions. It offers quick access to the most popular vector and raster formats and it is able to integrate data stocked locally or remotely through WMS, WFS, WCS services, as well as the connection to PostgreSQL-PostGIS, MySQL. Here are the main functionalities:

‒ spatial data visualization;
‒ complex layouts creation;
‒ transformations between different systems of coordinates;
‒ spatial data catalogs;
‒ spatial data analysis.

The alternative utilization of the two applications has determined the utilization of the better facilities for a specific type of operation, for example Quantum GIS for digitization, respectively the last GvSig version for symbolizing and displaying the data.
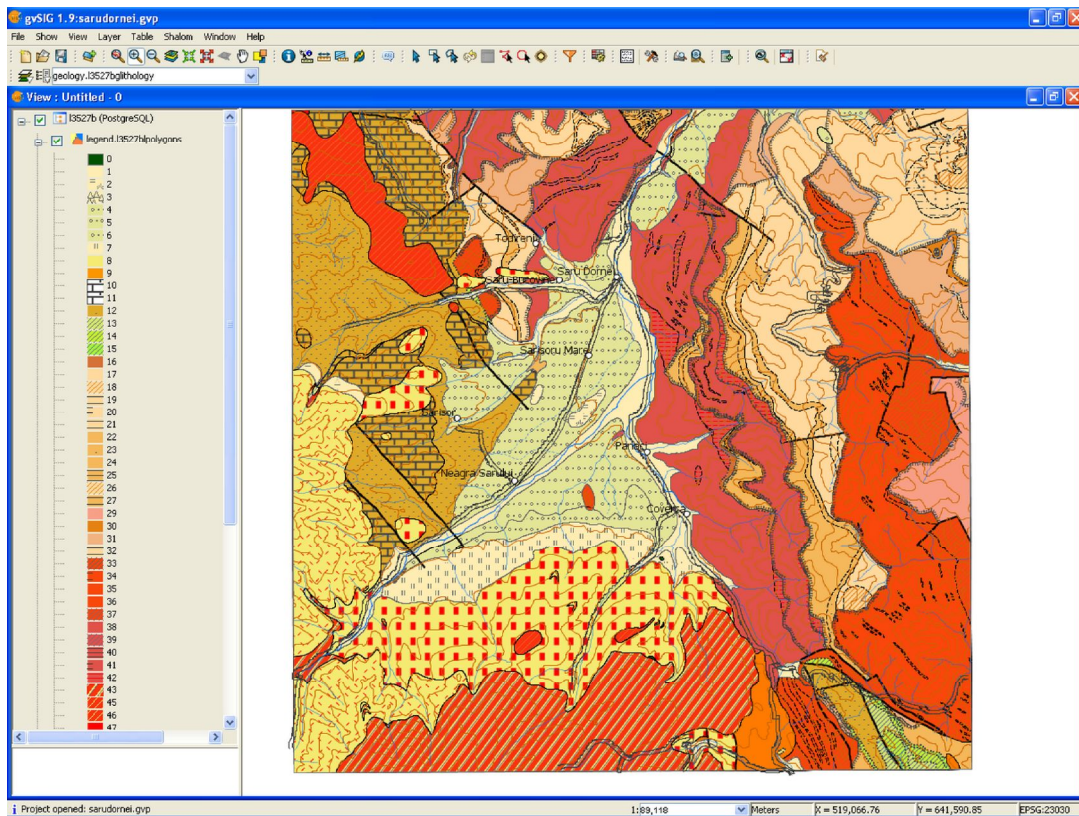

Fig. 3 – GvSIG, the desktop application for geospatial data

In order to add the data, a raster type (image) "template" was used, obtained through scanning and georeferencing in the Stereo 1970 projection system. The digitization and editing of spatial data are topologically introduced, practically the line type object being perfectly interconnected, avoiding topological errors (dangles, overlaps, slivers, etc).

3. Creating symbols and labels

The spatial data presentation as maps involves the symbolization of spatial elements according to a specific legend. On the basis of the associated attributes a field is used to perform a classification of the spatial objects, and every type will have a unique symbol. GVSig has possibilities for the utilization of different models of symbols for points, lines, polygons, texts (fig. 3).
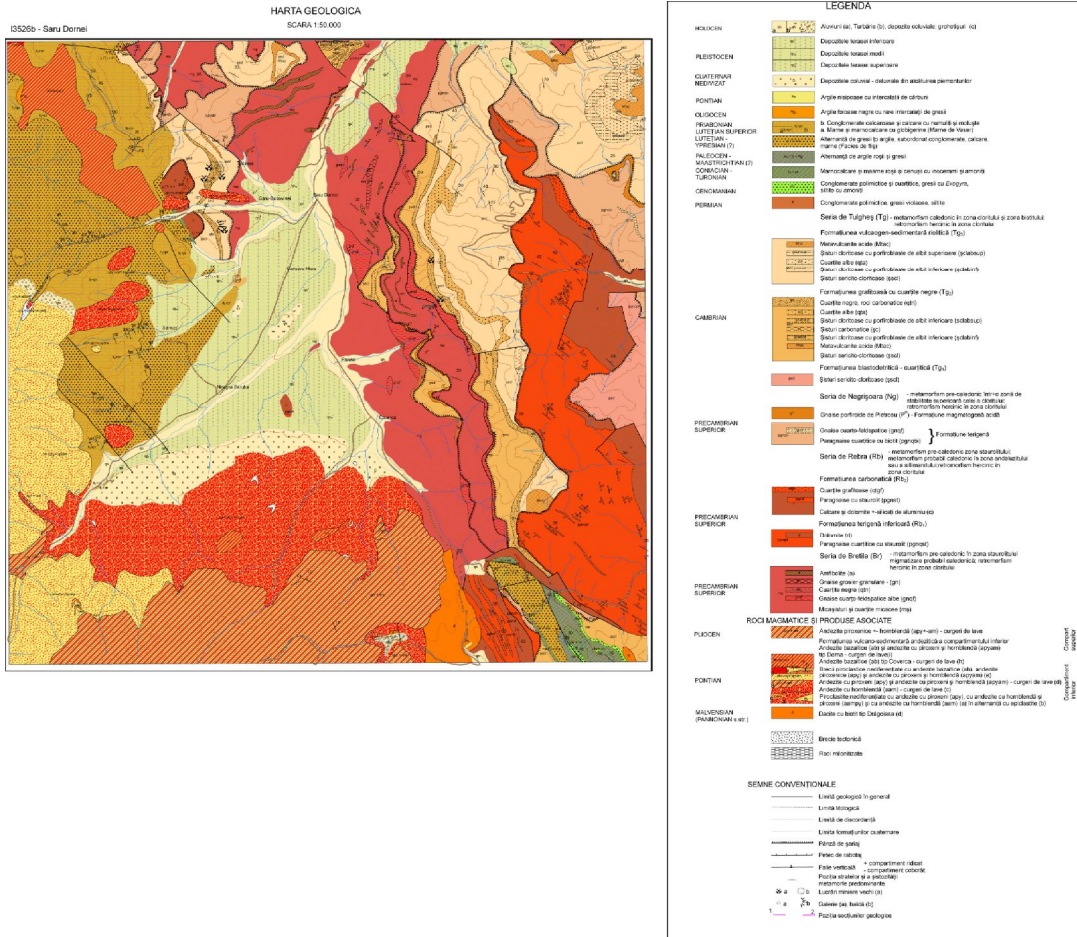

Fig. 4 – The geological map made by means of ArcGIS

New symbols can be added to the system for points and polygons, generated by other software packages for graphics (SVG format for points and jpg for polygons). The limitations within the symbolization of lines led to the application of the last GvSIG

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version, which allows the creation of complex symbols for points, lines, polygons and texts, like the ArcGIS system. Also, this application provides a displaying with performed possibilities to personalize the labels associated with the geospatial objects.

The legend of the map can be created by means of the specialized utilities or it can be personalized by creating a special data set (legend). The associated labels may be displayed from the fields with the attributes associated to the spatial objects (rivers, localities) or by creating a table by joining the spatial objects table with the associated dictionary table.
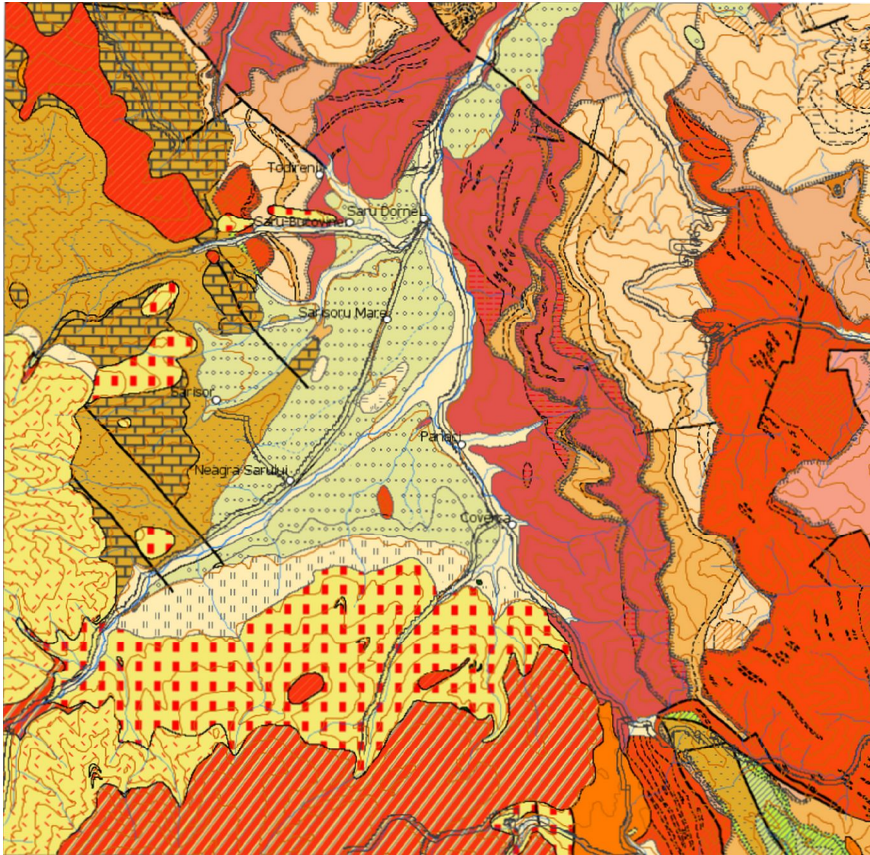

Fig. 5 – The geological map made by means of GvSig

Visualization, interrogation and data processing

The geospatial data is displayed as geological maps. The GIS applications have a specialized utility for creating a page which would contain the map sheet, the legend, geological sections, stratigraphic columns, associated layouts, etc. Here, one can establish the map scale and dimension (view), the paper dimension (A1 at 1:50.000 scale), orientation, images are inserted, resolution, frame, auxiliary texts, graphic scale, etc.

ArcGIS contains improved facilities for displaying the maps and it is recommended for special cartographic applications. Thus, the obtained map may have sensibly different aspects, based on whether they are created in GIS commercial (fig. 4) or open source (fig. 5) systems.

The advantages obtained by stocking the geospatial data in spatial databases (PostgreSQL/PostGIS) are represented by the following aspects:
- easier administration:
- simultaneous access in respect of editing and also for displaying in desktop or server type applications on the Internet:
- transactional way of working
- the possibility to introduce data protection and security systems:
- the possibility to perform periodical backups, in order to safely save the data.
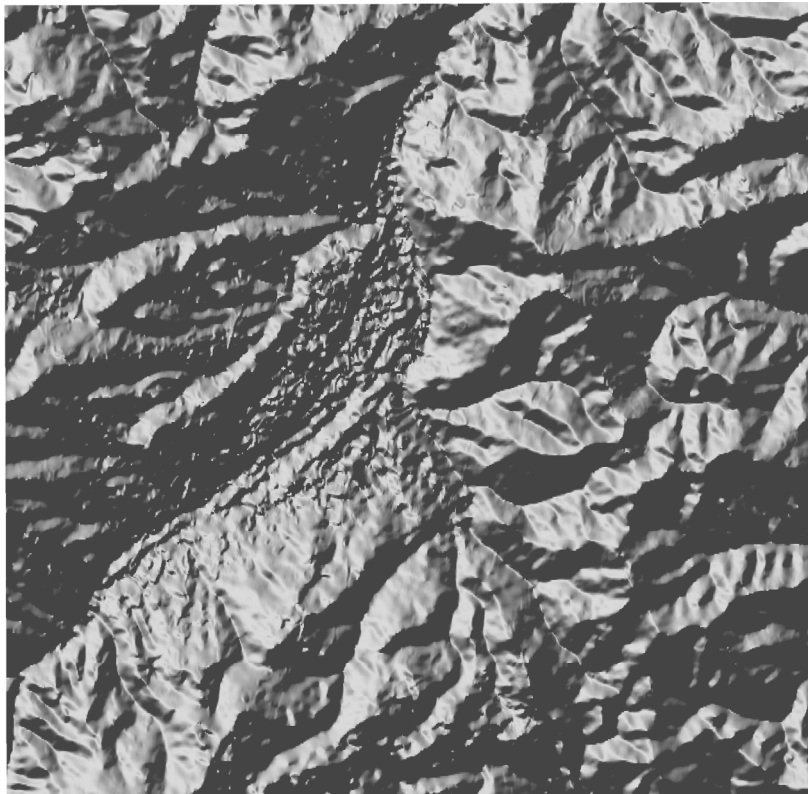

Fig. 6 – Shaded relief

The GIS systems provide a set of functions which determine the identification, combination or the selection of geospatial data. The spatial analysis represents a way of spatial data processing, so that it responds to clearly addressed questions within the current activities. By applying these, graphic objects result, which will be used further on. Practically, the data represented by maps will generate other maps.

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The spatial analyses are the ones referring to the graphic component (vector data and topological relations), responding to requirements like: visual identification, distance and area measurements, proximity analysis, network analysis, application of boolean operations for polygons from different thematic layers (union, intersection, clipping, etc), etc. The alphanumeric analyses represent interrogations of the database, using classical mechanisms (SQL): filtering of some entities on the basis of specific attributes, calculation of specific attributes, etc. The GIS applications has utilities of the Querry Builder type, with the help of which one can obtain multiple correct answers, which can generate other maps and which can be used in further analysis.
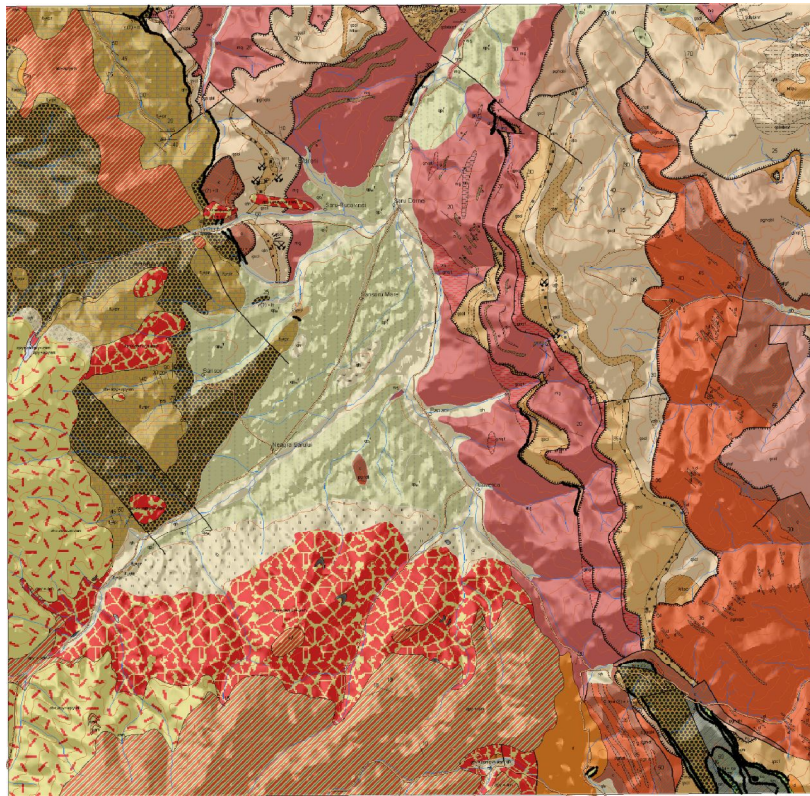

Fig. 7 – Vector data with lithology overlap over raster data with shaded relief

The raster analyses are applied either to the images obtained by means of scanning, air-photographing or by satellite, or to the representations generated by means of gridding, which build the model of the continuous geospatial phenomenona: local amplitude rendering, profile generating, iso-line generating, spectral analysis (functions applications – filters, satellite images in order to obtain discrete information), 3D analysis on DTM, 3D gridding analysis, etc. Shaded relief is a method that uses versant exposure in order to visualize the ramps' orientation in comparison with the cardinal points (fig. 6), using the shading generated by the light (hill-shade).

The hill-shade model may be obtained with specialized GIS applications (ArcGIS – Spatial Analyst or GRASS). By using the GRASS system, there was obtained the shaded relief image, along with other operations (cutting under the maps' limit (clip), re-projection in Stereo 1970 projection). In ArcGIS there were combined the vector and raster (hill-shade) layers and there was obtained the image shown in fig. 7. GRASS application detains an important number of functions for the analysis of the spatial data.
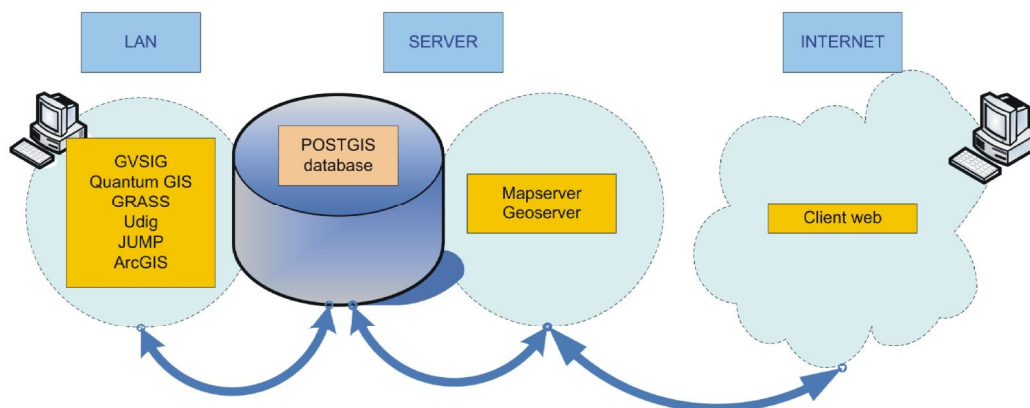

Fig. 8 – The functional scheme of GIS applications in relation to the database

The posting on the Internet by means of the navigators uses specific technologies (ArcGIS – ArcIMS, ArcGIS Server, Mapserver, etc), which transform the vector or raster spatial data in images which can be visualized by means of web programming languages (html, javascript, php, etc). Practically, the specialized module is an interface between the GIS data source (a GIS database) and the web client which displays the information as maps (fig. 8).

Mapserver is the name of the open source technology, created by Minnesota University, allowing the display and navigation through GIS type data, symbolization and interrogation of information. It is able to access files in proprietary formats or databases with spatial extension (PostgreSQL/PostGIS).

Conclusions

GIS open source applications are used more and more in every field dealing with geographic data. Their continuous development made them represent an alternative solution to commercial applications, surpassing the barrier imposed by the costs of such products and opening the access to administration, editing, visualization and analysis tools with respect to geospatial data.

By testing a big number of GIS open source desktop applications (GRASS, Quantum GIS, GvSIG, Mapwindow, Udig, Jump, Saga, Diva GIS, Ilwis) and server applications

(Mapserver, PostgreSQL/PostGIS), there was reached the possibility to use them for the geospatial data afferent to geological maps. The geodatabase term described by ESRI was adapted for spatial data and attribute stocking in relational databases was associated with spatial extension. That is how a more efficient administration of the data is obtained, with improved security and an easier access for desktop and server applications, facilitating the access to the local networks or the Internet.

The existing limitations determine the necessity of using them as alternative solutions along with commercial applications, using aspects connected to spatial data interoperability. Still, there are fields where the commercial applications bring an added value of possibilities, which respond to specific requests (for example the cartographic applications).

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***Environmental Systems Research Institute (ESRI) Inc., ArcGIS (ArcCatalog and ArcMap); quoted from http://www.esri.com.