Proposal for development of a database for engineering geological mapping

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Abstract: The information which results from engineering geological mapping can be stored electronically and is frequently stored in a geographic information system (GIS). However, often this information is stored in a disorganized way, even when the information is held electronically.

The information which results from engineering geological mapping can be stored, queried, viewed and analysed in the GIS and combined with other information in the GIS. This manipulation is a sensible way forward and can enable the linking of tables of data with the maps.

Another way to store, query, and view the information which results from the engineering geological mapping is to develop programs which do these tasks in a database system application. Also there are cartographic libraries which can help manipulation of the spatial data.

The programming language and cartographic libraries help organize and manipulate the information. So, applications can be developed with the results of engineering geological mapping. Also, the results can be dynamic and independent of GIS.

This paper has the objective of showing how to store, organize and manipulate the information from engineering geological mapping, whether it is stored in a GIS or by using a separate programming language. The information managed during this work was collected from the engineering geological mapping of the Ribeirão Preto region, located in south-eastern of Brazil, in the State of São Paulo. All the information was stored in a GIS for which were created queries and also, applications were carried out using programming language. This application showed the stored information through software screens, such as maps, images and tables.

Résumé: L'information qui résulte d'organisant la cartographie géologique peut être emmagasinée électroniquement et est fréquemment emmagasinée dans un système informatique géographique (SIG). Cependant, souvent cette information est emmagasinée dans une façon désorganisée, même quand l'information est électroniquement tenue.

L'information qui résulte de l'ingénierie cartographie géologique peut être emmagasinée, queried, regardé et analysé dans le SIG et combiné avec l'autre information dans le SIG. Cette manipulation est une façon raisonnable en avant et peut rendre capable le linkimg de tables de données avec les cartes.

Une autre façon pour emmagasiner, la question, et regarder l'information qui résulte de l'ingénierie la cartographie géologique il sera obligé à développer des programmes qui font ces tâches et dans aplicattion de système de données. Aussi il y a des bibliothèques cartographiques qui peuvent aider la manipulation des données spatiales.

La langage de programmation et les bibliothèques cartographiques aident organisent et manipulent l'information. Si, les applications peuvent être développées avec les résultats d'organisant la cartographie géologique. Aussi, les résultats peuvent être dynamiques et indépendants deSIG.

Ce papier a l'objectif de démonstration comment emmagasiner, organiser et manipuler l'information d'organisant la cartographie géologique, s'il est emmagasiné dans un GIS ou en utilisant sépare la langage de programmation. L'information, qui a été géré pendant ce travail, était de l'ingénierie la cartographie géologique de la ville de Preto de Ribeirão. Ce secteur est localisé dans Brésil sud-est dans l'Etat de São Paulo.

Toute l'information a été emmagasinée dans un SIG pour qui ont été créé des questions et aussi, il l'application a été exécuté utilisant la langage de programmation. Cette application a montré l'information emmagasinée par beaucoup de fenêtres qui montrent les cartes, les images et les tables.

Keywords: geographic information systems, database systems, engineering geological mapping, geodata, Ribeirão Preto, São Paulo, Brazil.

INTRODUCTION

Engineering geological mapping has shown its importance and efficiency as a tool and/or methodology, both for the analysis and evaluation of physical data and to provide advice for planning, be it urban or environmental. Hence, it is necessary to optimise the process of engineering geological mapping, because, this way, the final result can be achieved faster and with a better quality.

To achieve this, database managing systems (DBMS) and Geographic information systems (GIS) can be used to help in the storage, organization, integration, and handling of the data that are going to be used in the preparation of engineering geological maps and charts (input), the resulting information of the interpretation of engineering geological maps (output) and also the metadata.

GIS can be defined as a group of programs, equipments, methodologies, data and people (users), perfectly joined, to make possible the collection, storage, processing and analysis of geo-referenced data, and the production of the

information as well (Teixeira et al., 1995). Within this concept the database appears as one of the main elements in inner structuring of a GIS auxiliary the stored information in the geo-spatial analysis and as element outer to SIG for the storing of the information that will be handled and the resulting ones.

A database is defined as a modern method of storing and organizing information or a certain number of files that refer to an application, or a group of applications surrounding a group of data, or a computer system that stores registers (Crudely, registers are the lines of a table), being its general purpose to store, maintain and make the information available to its various uses (Date, 1999).

The main purpose of this study was to create a database with engineering geological maps and charts and the information on them. To do this, a database project was carried out using a GIS, for which were stored and gathered the available information and those that were resulting from the engineering geological mapping of Ribeirão Preto, Sao Paulo. An applicative (Graphic Interface) with database was also developed, additional to the GIS, using the same information. In this way, a study of the use of a database for the storage, organization and handling of the information extracted from an engineering geological mapping was carried out.

DATABASE FOR ENGINEERING GEOLOGICAL MAPPING

We can verify the utilization of a database in engineering geological mapping in various applications, due to the various advantages in storing the data produced, such as: the data independence; the control of redundancy, the assurance of the integrity, the security and the privacy of the data; and the facility of developing new applications; the automatic control of the relationship between the registers (information) and optimisation of the storing space of the information (Date, 1999).

In engineering geological mapping the database is generally linked to the GIS that is used for the spatial and geographic analysis. The database's applications in engineering geological mapping include various areas of engineering geology, such as: environmental, soil mechanics and urban planning.

Zuquette (1987) and Ferreira (1988) discussed the use of databases in engineering geology between the end of the 1960s and the beginning of the 1980s. In Table 1 is shown a summary of the systems that were described by the authors.

After the end of the 1980s, with the improvement of geographic information systems and database management systems (these are now more trust-worthy, safer, more complete and easier to use and purchase), the use of engineering geological databasing had spread all over the world. Table 2 lists some examples of database applications in engineering geological mapping after the 1990s.

STUDY AREA

The study area was the Ribeirão Preto Region, located in the north-eastern area of the state of São Paulo, Brazil, between the latitudes 21° and $21^{\circ}30$'S (south) and the longitudes $47^{\circ}30$'and 48°W (west), corresponding to an area of 2800km^2, although Ribeirão Preto city has an area around 700km^2.

Geomorphologically, the study region is divided into five units (IPT, 1981): aggradation relief characterized by the flooding basin of the region's hydrological regime; erosive reliefs, such as dissected plains with simple hillsides and ample hills and rounded reliefs; residual reliefs; as basaltic scarps, and transitional reliefs; and as the hillsides with local canyons.

Geologically, the region is located in the eastern portion of the Paraná Basin, constisting of sedimentary rocks of the Botucatu and Piramboia Formations, basic magmatites (basalts) of the Serra Geral Formation and recent alluvial deposits associated to the main drainages. The material that was not consolidated in this region is characterized by: hydromorphic material that follows the drainage; sandy and clayey residual material; mixed sandy material; clayey and sandy-clayey material. The mixed sandy material and residual material are spread all over the area.

In hydrologic terms the region is drained by the following basins: the Rio Grande in the north; the Tietê River in the south; the Pardo River; Mogi River and Sapucaí Mirim River in the Central Area. However, the Ribeirão Preto region is drained in the north, central and south portions by the Pardo River basin, Ribeirão Preto basin and Ribeirão da Onça basin, respectively.

According to Köppen's classification, the climatic type is AW, tropical with rainy summer and dry winter. The temperature of the coldest month is higher than 18°C, corresponding to the typical conditions of the Ribeirão Preto region, in the areas that have an average altitude of 600m. The average temperature during winter is 19°C and during summer 25°C. The average altitude is 518m, average annual rainfall is 1446 mm and relative humidity is 71%.

PROPOSED DATABASE APPLIED TO THE ENGINEERING GEOLOGICAL MAPPING

In engineering geology we can recognize that the information and/or data obtained by research are frequently stored in a disorganized way, even electronically. There is not a project for storing in a database, with the result that these data are not used by other professionals, because there are problems on searching, acquiring, handling, visualization and capturing of the stored data.

A database with geo-spatial information (positional and graphics) has some data that are difficult to store. Ordinary databases store numbers and chains of characters (letters, numbers and symbols). In spite of that, a geo-spatial

database, beyond those already cited data, can store graphs (lines, point, and polygon), images (pictorial data) and sites (geographic coordinates).

Bases for database development

Storing of information or data is related to restoring, handling, searching, consulting and displaying of these information or data. With advances in computer science, we can combine the generated information from engineering geological mapping in a GIS (Geographic Information System) or in an application linked to the database.

When a project on GIS is developed, information is organized in categories or fields, for example: thematic, cadastral, net, and image, according to the SIG modelling. The categories store the *layers or information plans.*

In the case of storing information in a relational database (DBMS, database management system), the information is organized in tables that have fields (columns), registers (lines) and cells that are the combination of a field with a register.

The project tried to develop a simple application, of easy utilization, that could store the information from the engineering geological mapping. The stored information should be easily available for visualization, and could give support for decision-making. In this study, pre-existing data on paper were used after examination, and registered in digital form.

When an engineering geological mapping is prepared, it is necessary to adopt some rules in the search and production of the information, so that this information can be stored in an organized way and so that the user can use it with confidence, easiness and quickness.

The Figure 1 shows an idea of the characteristics of the stored information and it is possible to get a general view of the kinds of information and the way to be followed.
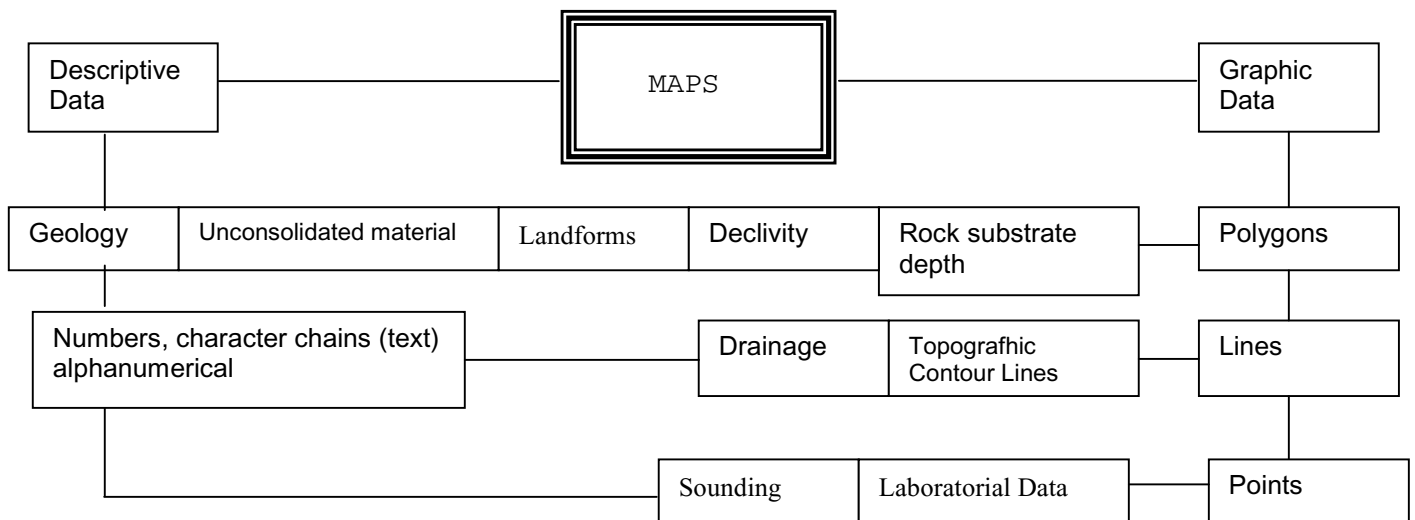

Figure 1: General Idea of the stored information (Entering Information)

The database project on GIS and external to the GIS was intended to be used by professionals experienced in engineering geological mapping. It offers the possibility of fast searching for information and demonstration of the project to interested people.

Support for database elaboration

In this study the data were obtained from the results of the engineering geological mapping of Ribeirão Preto Region carried out by Zuquette (1991) at scale 1:50,000 and registered on paper sheets. The data stored in the database were the following ones: topographic map, IBGE (1971), laboratory data and maps about the following aspects: geology, rock substrate depth, slope angle, landforms, unconsolidated material, descriptive data such as field and laboratory experiments and soundings.

The engineering geological mapping was developed according to Zuquette's proposal (1987).

Used Computational Resources

To digitize the maps AUTOCAD2000 from Intergraph was used together with the free version of SPRING 4.0 developed by Instituto Nacional de Pesquisas Espaciais of the Brazil (INPE, 2003). The storing of the non-geo-spatial data used SGBD ACCESS2000, developed by Microsoft and for the storing of the handling and integration of geo-spatial data SPRING4.0 was used. The application was developed in Visual Basic 6.0 of Microsoft (Halvorson et al, 1998), and to handle geo-spatial data, external to GIS, Visual Basic 6.0 and the library map Objects 2.2, developed by ESRI (Environmental Systems Research Institute, 2004) were used.

Data Characteristics

The engineering geological maps and charts resulting from the engineering geological mapping described the characteristics of the components of the geological environment and their behaviour with different uses, according to

Zuquette and Gandolfi (2004). According to those authors for engineering geological mapping a complex geological model must be considered focused on the parameters of engineering, while the geotechnical model is focused on the application.

The data were stored into two different ways, a GIS and an application. On SPRING-GIS, the data were adapted to the program mode as showed in the Figure 2 that is the conceptual model of the project, too. Maps were registered as: cadastral, thematic, numerical model of the terrain (MNT), image and nets.

In a geographic database that recognized by the name, in that case "Ribeirão" and this database is modeling conceptually with enties, for instance, information plans, that are not special and geoobjects.

In the application the data were registers based on the objects, following the idea of the orientation to objects (Pender, 2004). The objects used in the application, were basically: map control, used to hold the information plan (layers) in shape files; DATAGRID in ADODOC, used to hold the tables. These objects are put on a formulary, object form (Petroutso, 1999). The application has 13 main formularies and 8 secondary formularies. In Figure 3 is shown a general flowchart of the elaboration of the application.
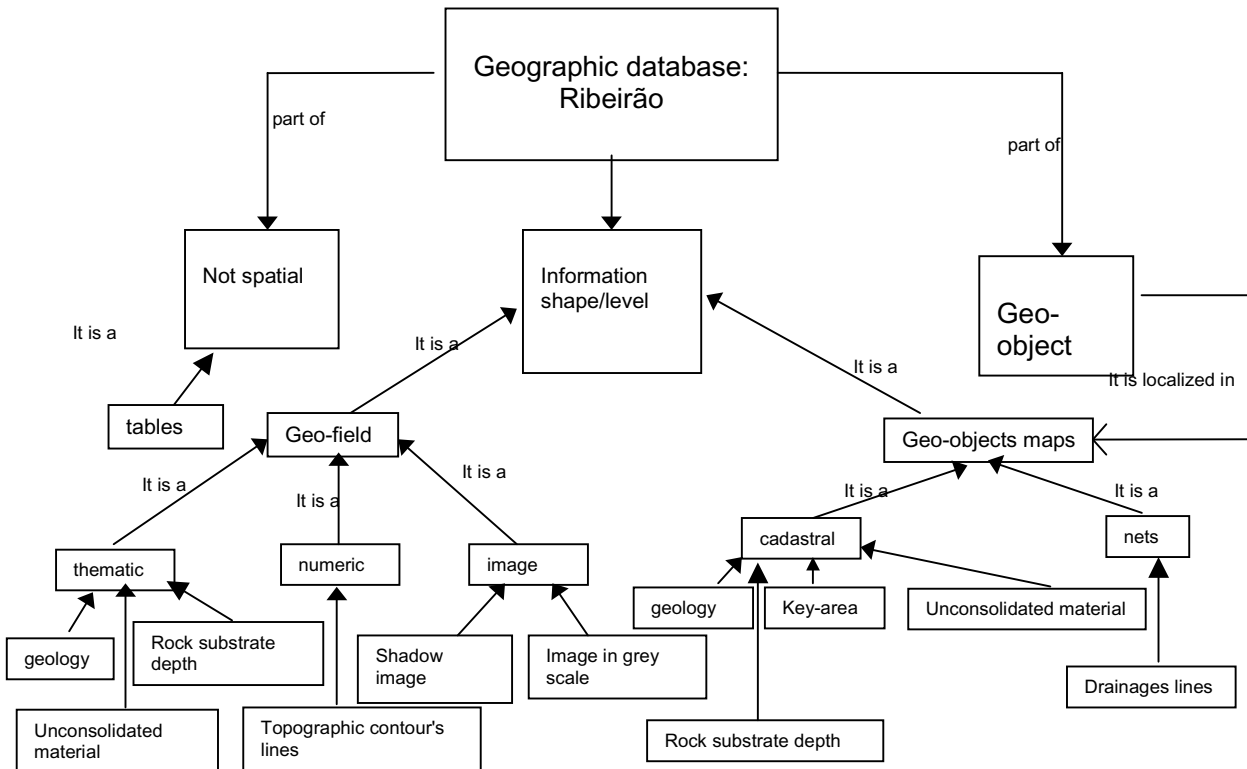

Figure 2: Conceptual model of the GIS adapted to the study database.

Phases in the development of the database

It was realized an integration of the data in SPRING 4.0 and another one on the place of the program language Basic Visual 6.0.

A project was created in SIG-SPRING, for the storing, visualization, searching and handling of the information. To access the information is needed to activate the project and the database named Ribeirão.

An application was developed in Visual Basic with the stored data of geo-spatial (maps), tables, images, and other data. To access the geo-spatial data tools were used from the library MapObject.

Tables were elaborated on SGBD and ACCESS using the controls DATAGRID and ADODOC of Visual Basic.

For realization of this study the following steps were taken:

- Theory background
- Data collection
- Analysis of the condition (register form, etc) of the collected data to be stored
- Selection of the software
- Data Storage
- Storage and organization of the cartographic and non-cartographic items on SIG (data integration)
- Storage and organization of the non-spatial data on SGBD (development and attribution of the tables)
- Analysis of the stored data
- Development of the interrogation methods on SIG.

- Exportation of the information plans (layers/maps) of GIS to be used in the application.
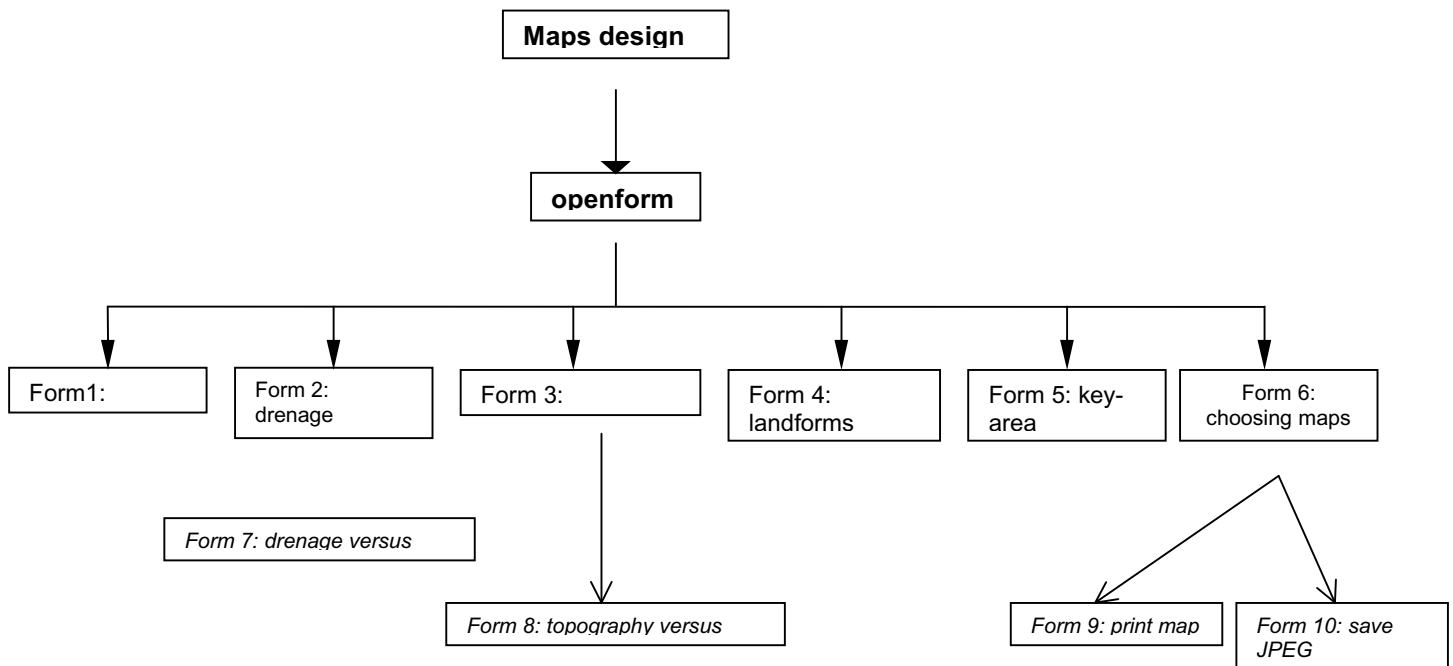- Development of the locative in Basic Visual to do the data integration.

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Form1:	Form 2: drenage	Form 3:	Form 4: landforms	Form 5: key-area	Form 6: choosing maps

Form 7: drenage versus

Form 8: topography versus

Form 9: print map   *Form 10: save JPEG*

Figure 3: Model of the Applicative

QUERIES OF THE DATABASE

To consult the database in the GIS it is necessary to activate the Ribeirão project and database, on GIS-SPRING (see Figure 4). Information is shown in categories (thematic, cadastral, net, DTM and images). Data about geology, unconsolidated material, rock substrate depth and drainage are in cadastral and thematic categories, slope angle and landforms are in the thematic category, topography is in the numerical model category. The drainage system is in the net category. The data about observation and sampling points are in the cadastral category.

To consult the information in the application it is necessary to visualize the specific information on the main software screen (geology, unconsolidated material, drainage, etc) which can be accessed by a command via the left click mouse buttons (Figure 5).

After this action is carried out, a second window will be opened, where a layer (Map) is portrayed, which shows the spatial distribution of the consulted aspect and a table that contains the descriptive characteristics of the layers (Figure 6). In a general way, this is how the application works, although there is other information to be consulted and other kinds of consultation.

DISCUSSION ABOUT THE STORAGE AND THE QUERIES

The data electronically stored can be used in the analysis of the geological environment to assist in urban and environmental planning, for selection of possible locations for sanitary landfills, urban expansion, hazard areas and to orientate development. In conclusion, it permits a general view of the restrictions on and potentialities of the region.

This work tried to show the importance of the use of a database to store information generated by engineering geological mapping. It has verified the facility for storing this information in electronic form and the quickness in consultation and handling of data and the security of electronic storage.

The two kinds of storage, integration and handling of the information in GIS and using the programming language present advantages and disadvantages, for example: for the information stored on GIS, follow the pattern of storing of GIS and it is not necessary to write routines for certain activities. For the application, the handling of the information is more dynamic and faster than in the GIS and more flexible for visualization, although, routines to effect the activities must be written.

The application was developed in a programming language, using a specific library for the visualization of the geo-spatial data. The importance of storing the information in an application is that it makes the visualization of the stored information quicker, more dynamic and more flexible than in the GIS.

CONCLUSION

An application to store the information from engineering geological mapping makes the stored information easier to handle and visualize by users, while GIS helps a lot with storage, handling, organization and special analysis of the information, although the biggest difficulty is to transport the database (project) to other machines and demonstrate the project to other people.

Two basic ways of storage, organization, and integration of the information from engineering geological mapping (SIG AND/OR APLICATIVE) have been demonstrated.

From the application an Electronic Atlas with engineering geological maps and charts can be developed, in addition to the possibility of developing a system with geo-referenced engineering geological information and a small GIS.

Taking a look at the databases that were used in a engineering geological mapping it can be seen that:

- The first database systems for the engineering geological mapping were created from programming language, they did not use SGBD, and also did not use SIGs because these tools could not be trusted;
- Nowadays in the development of databases uses DBMS and GIS, because they are more efficient in the organization and storage, recovery and integration of data and still make easier the development of database.
- There is a classical form or even a standard form for using the database;
- The data can be handled, joined to maps and even be useful to elaborate new applications.
- Most of the initial systems used information that came from 'logs' of soundings, but the new systems use data that comes from other sources, which can verify the diversity of applications.

Other important applications include hypermaps that are maps that give access to other information (photos, tables or other maps), and because the system has a link, these kinds of maps are just visualized on a computer screen.

This approach increases utilization of information in the engineering geological database. In this way, the database will be able to be provide information instantly, and also be able to receive information in real time.

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Table 1: Database that were made in Europe around the 1970s and 1980s.

Year	Country	Database Descripion
1979	ITALY	GERET Syatem used in Italy in Venice, with information about logs and soundings.
1978	ENGLAND	GEOSYS System(CRIPPS) used on England to store logs of soundings.
1969	FRANCE	DataBase used in France, in Des Ponts et Chausseés lab that used logs of sounding data.
1971	SCOTLAND	Database from registers of soundings in the area of Edinburgh in Scotland
1971	SCOTLAND	Database providing logs of soundings from Central Scotland.
1986	SPAIN	Database with sounding logs information from the city of Madrid, Spain, Geo-Madrid.
1981	ENGLAND	Geoshare System that stores sounding logs used in England.
1981	SWEDEN	Swedish Database used to store general soil information.
1982	UNITED STATES	Databased developed in Indiana, USA, with information of geotechnical characteristics of the soil.
1979	ENGLAND	Database from Newcastle-upon-Tyne in England with information from maps about the physical environment.
1984	MEXICO	Database of México City, Geodata Base System.
1976	UNITED STATES	Computer Mapping System in Fairfax, Virginia in the USA that stored terrain information such as topography, hydrology, characteristics of rocky soil.
1967	UNITED STATES	Database used in the elaboration of recommendations for using soils, in which was stored information of the characteristics of the physical environment of a region in the USA.
1976	SOUTH AFRICA	Database to the urban planning of Johannesburg in South Africa.
1971	USA AND CANADA	GCARDS System developed in the USA and in Canada.
1969	BELGIUM	Database from Belgium, developed in the Laboratory of Soil Mechanics, with information about geotechnics, geology, pedology, hydrology.
1972	CANADA	Database geoscientific used in the digital mapping of Canada, with information such as lithology, type of soil, soil property and water level.
1978	AUSTRALIA	Database developed by the Commonwealth Scientific and Industrial Research Organization, in Australia.

Table 2: Summary of the application of Database in Engineering geological mapping from the 1990s.

AUTHOR	LOCAL	SUBJECT
Ferreira (1988)	São Carlos – SP-Brazil	Geodata, for mapping.
Junqueira and Silva Jr (1991)	Rio de Janeiro-RJ-Brazil	Register of slope problems in road works.
Moreira (1993)	Aguaí - SP-Brazil	Geotechnical data for mapping.
Pinheiro and Especchit (1994)	Brazil	Information about federal roads.
Kunte (1995)	---	Information database in marine geology.
Laxton and Becken (1996)	Wrexham – England	Storing of information in geological maps.
Dikau, Cavalin and Jäger (1996)	Europe	Register of weight moves.
Meira and Calijuri (1996)	Ouro Preto – MG - Brazil	Automation of the elaboration process of engineering geological mapping.
Tarvainem and Paukola (1996)	Finlândia	Geochemical information about underground soil and water.
Coutinho, Moteiro and Oliveira (1996)	Recife-PE Brazil	Information about organic clay.
Colman-Sadd, Ash and Nolan (1997)	Newfoundand – Canadá	Storing of geological subtitles.

| Haastrup et al. (1998)	Sicíliy Italy	Geotechnical, geological information.
Nathanail and Rosenbaun (1998)	Northeast of England	Data of sounding logs.
Brodie (1998)	South of Australia	Superficial waters.
Diniz (1998)	São Paulo Brazil	Geoenvironmental information
Kim, Pyeon, Eo (2000)	Seul - Corea	Urban Streets.
Silva (2000)	Portugal	Engineering geological cartography.
Calijuri et al. (2001)	Viçosa – MG- Brazil	Engineering geologicalmapping, information viewing system.
Souza (2001)	Litoral de São Paulo-Brazil	Geoenvironmental Information
Cavaleiro (2001)	Covilhã Portugal	Geoenvironmental Information
Chamecki et a.l (2001)	Curitiba – Brazil	Soil strength for foundation.
Salamuni and Stellfeld (2001)	Curitiba - Brazil	Geological and geomorphological.
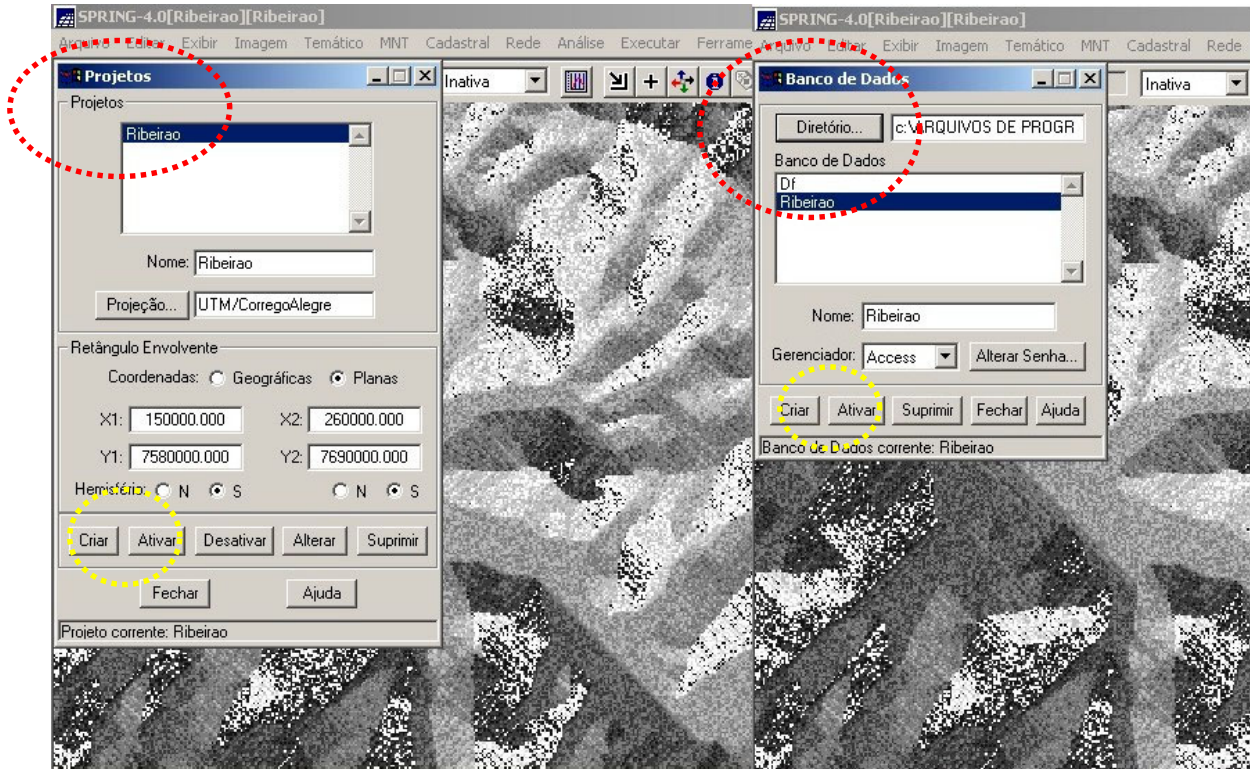
Figure 4: Activating the data project named Ribeirão on GIS – SPRING (Yellow dotted line)

Figure.5: Main window of the application.

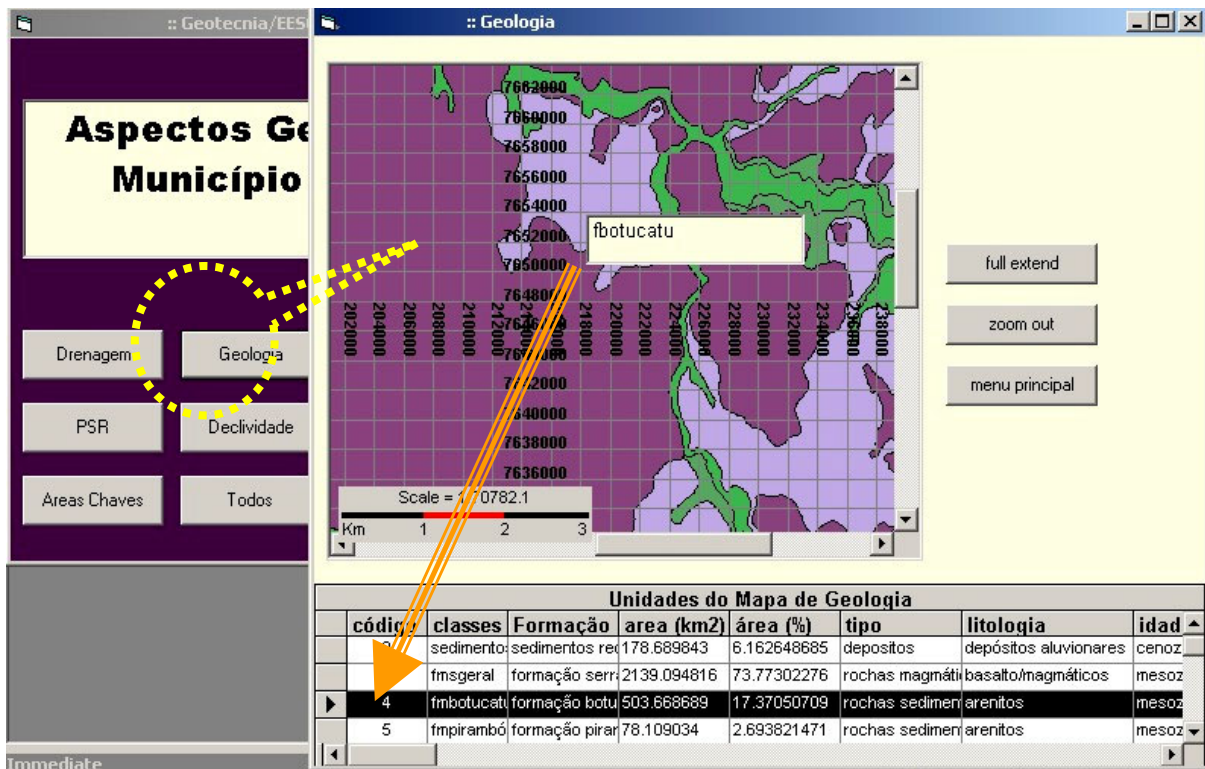**Figure 6**: Second screen of the application, showing the information about geology.