

GEOMIST. Integrated and Harmonised Information Service for the Management of Mineral Resources in the Iberian Pyrite Belt

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ABSTRACT

The Iberian Pyrite Belt is one of the most important metallogenic areas of Europe running across the South of Portugal and the South-West of Spain, where a huge amount of geological and mining data produced during decades of exploration for massive sulphides in both countries is available. However, the information is held in disparate and dispersed national databanks mainly at the Geological Surveys of Spain (Instituto Geológico y Minero de España, IGME) and Portugal (Instituto Geológico e Mineiro, IGM).

To satisfy the users request, mainly mining companies and administrative bodies regulating mining rights, environmental issues and land use in the area, IGME and IGM have built, under the funding of the European Commission within the ESPRIT project n° 24481, an information service capable of providing integrated and harmonised geological and mining information across the borders.

The service is based on web servers installed at IGME and IGM in Madrid and Lisbon. Users, i.e. anyone connected to the Internet will be able to access and query the institutional databases through those web servers. The database servers can be interrogated in English, Portuguese and Spanish through the IGME thesaurus on Earth Sciences.

Key words: data bases, Iberian Pyrite Belt, information systems, Internet, mineral resources

GEOMIST. Servicio integrado y armonizado para la gestión de los recursos minerales de la Faja Pirítica Ibérica.

RESUMEN

La Faja Pirítica Ibérica es una de las provincias metalogénicas más importantes de Europa, en el Sur de Portugal y Sur-Oeste de España, con una gran cantidad de datos geológicos y mineros producidos en los dos países como consecuencia de la exploración durante décadas de sulfuros masivos. Sin embargo, la información disponible en los bancos de datos nacionales de los Institutos Geológicos y Mineros de España (IGME) y Portugal (IGM) no está armonizada.

A petición de los usuarios, principalmente compañías mineras, administraciones a cargo de la regulación de los derechos mineros, aspectos ambientales y de uso del territorio, el IGME y el IGM han desarrollado, con subvención de la Comisión Europea dentro del proyecto ESPRIT n° 24481, un servicio electrónico de información para suministro de datos geológico-mineros integrados y armonizados a ambos lados de la frontera.

El servicio se basa en Servidores de Internet instalados en Madrid (IGME) y Lisboa (IGM) a través de los cuales los usuarios pueden acceder a consultar las bases de datos institucionales de ambos Institutos. La consulta se puede realizar en español, portugués e inglés a través del tesoro IGME en Ciencias de la Tierra.

Palabras clave: bases de datos, Faja Pirítica Ibérica, Internet, recursos minerales, sistemas de información

Introduction

The need for information services suitable for the management of mineral resources in specific mineral

areas is a must to achieve sustainable exploitation of the mineral resources, as requested by the administrations, mining companies and the society at large.

Being the Iberian Pyrite Belt one of the most

important metallogenic areas of Europe for the exploitation of massive sulphides, the mining exploration data held by IGME and IGM are not harmonised being held in disparate formats and coordinate systems as well as in different languages. So that, data being presently gathered by companies engaged in mining exploration and exploitation activities in the area are held in disparate data banks, not conforming any pre-specified data model or standards. On the other hand, there is no on-line geological information service addressed to regional bodies in charge of mining permits delivery and environmental protection.

In this situation it is difficult to determine what relevant data are available since IGME and IGM had to be approached separately, what it is certainly a barrier for both mining investment and sustainable exploitation of the mineral resources.

To solve this problem, the Geological and Mining Institutes of Spain, IGME and Portugal, IGM decided in February 1997, with the financial help of the European Commission within the European Strategic Program Research for Information Technologies, ESPRIT Contract nº 24481, to develop an information system (Delgado and Herrera, 1999) to provide on-line geological and mining data at the following levels:

- Catalogue level, what type of data, i.e. boreholes
- Index level, where about are located the data, i.e. x, y locations
- Metadata level, data about the data, i.e. length, time extension, updating,...
- Geo-data level, factual geological and mining data in digital form, i.e. logs

In addition, interactive database queries and mapping services and other type of services will be offered to mining companies, operating in the Iberian Pyrite Belt, as well as to other interested entities and regional bodies in charge of land planning and environment preservation in the area on a cross-border framework.

The major objectives pursued were:

- To integrate the geological and mining information existent on a cross-border metallogenic unit
- To enable access to geo-information held in distributed and disparate national data banks
- Setting-up of an information system containing:
 - Geoscientific information at IGME and IGM
 - Mining exploration data, reducing the information search costs of mineral exploration
- To provide an unique access point to metadata and geo-data over the web

The service is based on web servers installed at IGME (Spain) and IGM (Portugal), in Madrid and

Lisbon. Users will be able, according to their respective user category, to access the institutional databases on: Mineral Occurrences, Exploration Drill Holes, Exploitation and Prospecting Mining Data, Radiometric, Spectrometric and Aeromagnetic Data as well as Geological and Geophysical Maps, through those web servers.

Problems addressed, aims, tasks and deliverables

The building up of the GEOMIST World Wide Web Information Service providing access to 2-D and 3-D geological and mining data had to face some major problems:

- The absence of standards to disseminate geo-data across Europe, with a need to adopt a standard to describe geological and mining data across borders
- Harmonisation of geo-referenced geological information stored under different co-ordinate systems as well as different data models, lexicons and languages. An effort was paid to the development of tools for standardisation of cross-border geoscientific data, to get an unique data description of the real geo-data: geological maps, mineral occurrences, topography, drill holes, geophysics, ...
- No availability of 3-D geological models and representation and retrieval tools to describe and manipulate geo-data
- Development of thematic and geographical 2-D and 3-D search and interactive mapping services through the web

In addressing these problems GEOMIST was in close relation with two other ESPRIT projects:

- GEIXS. Geological Electronic Information eXchange Systems. The objective of GEIXS is to standardise the data descriptions up to the metadata level, creating a metadata web server of harmonised geoscientific information as an on-line index to European geoscience data.
- OMEGA. Object Oriented Environment for Geosciences Applications. The main aim of OMEGA is the creation of a 3-D development framework to deal with real geological objects

Both Geological Surveys IGME and IGM are also participating in the development of the GEIXS metadata web server (Laxton *et al.*, 2000), while the third partner of GEOMIST, the French company Matra Data Vision (MTDV) is participating in the development of the OMEGA components, providing the basic software toolkit CAS.CADE to develop the 3-D applications tools.

The links between the three projects were established so that GEOMIST adapted and extended the 2-D metadata model defined within GEIXS as well as the OMEGA 3-D components to build up the 3-D geological model and to develop the 3-D demonstrator on specific sets of geo-data.

To achieve these objectives, the following work-program was established:

- Data Inventory and Modeling
- Redesign of Databases and GIS
- Computer Platform and Communication Network
- Design and Construction of the Metabase
- 3-D Representation & Retrieval Applications on Geodata
- Build-up and Validation of the Demonstrator
- Dissemination Actions

Through the development of this workprogram, some major achievements were obtained, such as:

- A common data catalogue and data dictionary
- Harmonisation and reorganisation of IGME and IGM databases with unified structures
- Design of a common Metabase and of 2-D and 3-D data models for geo-data
- 3-D application tools to manipulate geo-data
- Development of a live web server and services, including:
 - Metadata query
 - Thematic and geographical searches on factual geo-data
 - Interactive mapping service
 - System Security to deal with confidential or restricted access data

Harmonisation and reorganisation of IGME and IGM data bases

The first problem addressed was the harmonisation and re-organisation of the respective data bases at IGME and IGM, with unified structures, to allow the design of a common Metabase (Delgado *et al.*, 1999).

First a common Data Dictionary at the geodata level was developed for seven selected data bases at IGME and IGM:

- Geological Mapping
- Mineral Occurrences
- Gravimetric Data
- Aeromagnetic Data
- Radiometric Data
- Exploration Drill Holes
- Prospecting Data

The common Data Dictionary is needed to get an unique description of the data and of the derived algorithms and attributes. This allows the harmonisa-

tion and integration of all the data with unified semantics and characteristics, allowing the redesign of common structures for each database. To generate the Data Dictionary on the Iberian Pyrite Belt, first the inventory of the available data sets at IGME and IGM was completed, combining and harmonising the data catalogues of both organisms.

Harmonisation of data sets started with the generation of a co-ordinate transformation application, to reference all the geodata to a common projection system, UTM-zone 29.

Some guidelines were also produced for homogenisation of cross-border data set, namely topographic maps, geology model, geological maps and legends, geophysics and documents.

Therefore, a toolbox was developed to load and reorganise database objects according to the data model.

Once the data dictionary and harmonisation tools were produced, the redesign of databases and geographical information components of the Information System could start.

To prepare the data model a questionnaire on GEOMIST searches & services was prepared and circulated to members of the User Groups previously established in Spain and Portugal, integrating the main mining companies operating in the area plus the regional administrations in charge of mining permits delivery.

In this questionnaire, specific questions on the possible queries the user might be interested in making while exploring the GEOMIST Information Service were raised.

The inputs from the questionnaire were considered in the design of the Conceptual Model. In this model the defined entities are represented together with their relations and cardinalities, facilitating the planning of the user queries. The data model represented in CASE tools formats were then developed for each one of the common selected databases

Once the conceptual models are established it is possible to build-up the computerised Internal Logical Models, defining the group of tables integrating each database with their respective attributes and access keys

Care was taken to make the conceptual and internal logical models robust enough to support the external models, i.e., the anticipated user queries derived from the answer to the questionnaire. The final data model is based in the Entity-Relation method resulting in the definition of the geological objects (entities) and their attributes, i.e. geological properties or results of specific measurements. The Geo-relational 2-D model for geo-data assumes that

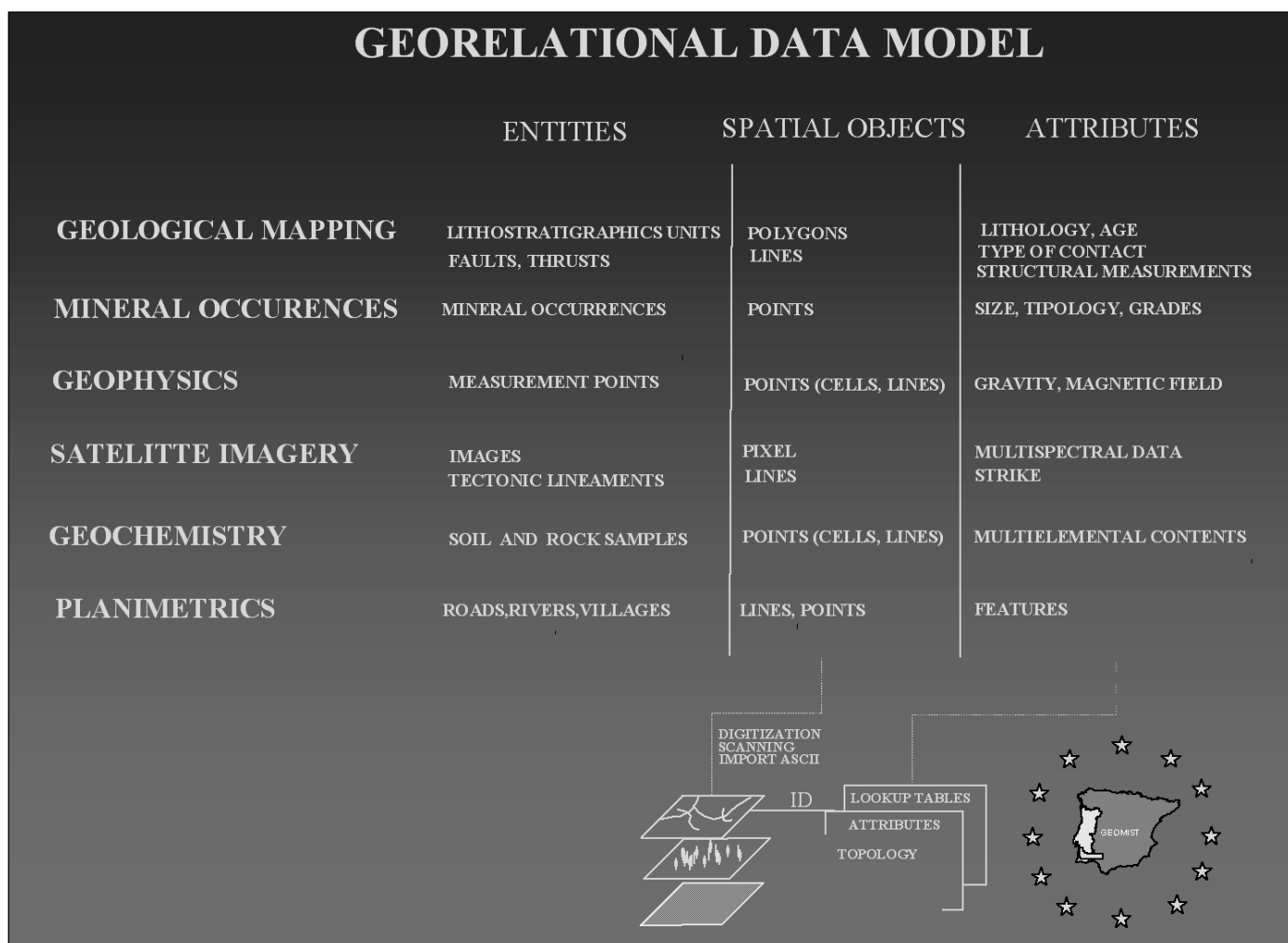


Fig. 1: GeoRelational Data Model
 Fig. 1: Modelo Geo-relacional de Datos

geological maps can be described as a collection of structural information, point and line measurements and basic geological units (polygons) mapped at a certain scale.

From these models and through the institutional data base tools at IGME and IGM, i.e. ORACLE for relational data bases and ARC/INFO for maps, a new and uniform data base structure and population at IGME and IGM was achieved. Descriptive data, i.e. attributes stored under ARC/INFO were migrated to ORACLE DBMS through a specific application program developed for this purpose. ARC/INFO coverages are used to store the cartographic information.

Geomist metabase

The generation of a common Metabase, that is "data

about datasets" is essential to let users know what information is readily accessible into the system. It includes information about the content, representation, extent (geometrical and temporal), spatial reference, quality, context and administration of the data.

The GEOMIST Metabase was generated under ORACLE following the GEIXS Metadata Model, based in the draft of the European standard prEN287009 and based on the common GEOMIST data dictionary as well as on the meta-information associated to each database.

The Metabase is accessed through a catalogue layer including the categories or general Subjects. The key Subject Detail provides access to each one of the metabases, which in turn allows access to the geo-data. Both fields Subject and Subject Detail are available in English, Portuguese and Spanish, and thus a multilingual access is available.

Computer platform and communication network

The enhancement of the internal Local Area Networks and Internet connections at both sites had also to be accomplished. The architecture of the adopted solution is based on the Client/Server model in which all the components: servers, routers, client workstations and software are based in standard open systems as it is shown in the figure.

Technical operational requirements were prepared for hardware (servers and routers), software, web services and Internet security and remote communications as described below.

Servers

Servers with symmetrical multiprocessing capacity, simple architecture, scalability, robust enough with high capacity level and high performance to manage technical and transactional UNIX applications.

The following servers and workstations have been integrated at both sites IGME and IGM

- ORACLE Data Base Servers. To store the Metabase and the data base attributes

- ARC-INFO GIS Servers. To store the cartographic coverages
- WEB Servers
- CAS.CADE Workstations for 3-D development
- Server for Interactive Mapping Services

Routers

Commercial routers were used at both sites to support TCP/IP protocols and communication links with priority system for traffic control and data compression. Interfaces Ethernet, ATM and ISDN are available.

Software

Software with logical interfaces based in the Client/Server architecture, providing heterogeneous client access to the database servers. Textual and attributes retrieval facilities to ease user search.

World Wide Web Services and Internet Security

Web pages servers functions and Proxy functions are

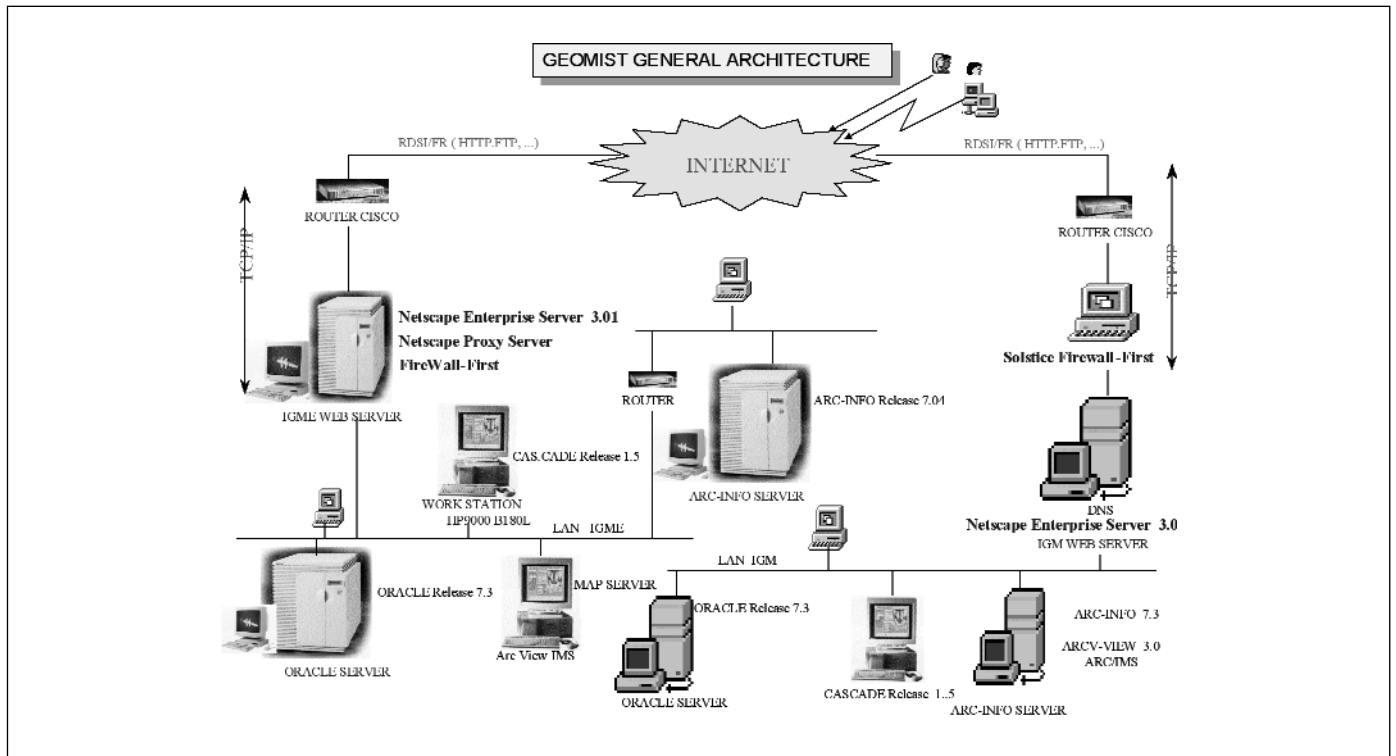


Fig. 2: GEOMIST General Architecture
Fig. 2: Arquitectura general de GEOMIST

implemented through the installation of commercial software products, mainly NetScape products. Internet security is considered by hardware and software FIREWALL systems.

3-D Representation and retrieval applications on geodata

The development of three dimensional (3-D) geological models of selected geo-data sets and the generation of application programs for 3-D representation and retrieval of geological data through the web, were also considered to implement the 3-D services consisting in the construction, representation and visualisation of 3-D geological objects (Cerdán F. P., *et al.*, 2001), based on recent developments in 3-D modelling and visualisation methods allowing the use of vector models (Hack, R and Sides, H. 1994).

A data set of 3-D geo-data consisting in exploration drill holes, the digital elevation model of the territory and the geological map of a specific area within the Iberian Pyrite Belt was selected to develop the 3-D geological model for the GEOMIST demonstrator.

The description of the geological objects and of their attributes was made, by using interpolation methods and establishing the relations between the geological objects (Raper, J.F. and Kelk, B. 1991). Three main type of elements were defined to rebuild the structure and geological composition of the selected drill-hole data set:

- geological objects representing entities related with the composition and morphology of the Earth, either tangible rock bodies or inferred objects resulting from the characterisation of tangible objects when one or more attributes have the same value, i.e. mineral occurrences.
- observations or surveys of spatial points, lines or surfaces in which the shape, extension, position, limits, property,... is measured.
- methods or techniques applied to estimate or interpolate geological attributes at non observed points to rebuild the geological objects.

This theoretical framework was applied to the selected drill-hole data set to build-up the 3-D model based on the associated attributes of the rock bodies: lithology, age, density, mineral composition, grain, size and texture. The rock bodies are described as volumes divided in one or more blocks limited by either arbitrary or geological surfaces, such as faults, contacts or topographic surfaces and grouped in hierarchical categories: members, formations, groups and super-groups. The mineral occurrences are described by their main attributes: host rock, paragenesis, structure and size. The drill-holes are considered

as linear observations described by their main attributes: initial co-ordinates, direction and dip. A diagram in case-tool format of the theoretical 3-D model, showing the relation and cardinalities between the different geological entities is presented in the figure.

The modelling procedure started with the raw data either point, linear or surface observations. From these raw data and using methods of interpolation or interpretation, the structural framework, structural grid and lithostratigraphic surfaces are rebuilt.

Once the 3-D development framework was defined, it had to be implemented into the 3-D demonstrator of the GEOMIST Web Server. This was done by reusing results from the ESPRIT project OMEGA in order to develop tools to visualise OMEGA objects and exporting the OMEGA entities as VRML files that can be visualised through Internet by standard Web browsers

First the identification between the GEOMIST geological objects and the OMEGA components (oil-industry oriented) was made as follows:

- Well files containing in-depth information on the trajectory, markers, facies zone, petrophysical properties and dip were identified with the GEOMIST drill-holes.
- Grid files of 2-D surfaces of regular and irregular grids, i.e. structural information in matrix format with values of the Z co-ordinate were identified with the GEOMIST digital elevation model.
- Polygon files defining areas with convex limits and specific characteristics such as mining license areas, faults, geological zones with stationary properties,...

Application programs were generated to transform the GEOMIST geological objects into OMEGA objects with specified OMEGA ASCII file formats that could be loaded into the envelop editor OMEGA application generating boundary representations of the horizons, drill-holes and subsurface.

The development of the 3-D demonstrator tools was made using Java 1.2, CAS.CADE 1.5B and OMEGA products to be able to visualise bore-holes, horizons and convex surfaces. Java was used for the graphic user interface and CAS.CADE and OMEGA to create and visualise the 3-D data model of the geological object. These developments are based on C++ and can be reused on personal computers.

A user guide for the 3-D demonstrator was prepared containing information on the implemented facilities for 3-D representation and retrieval of geo-data:

- 2-D and 3-D Graphic representation of the 3-D data model including view manipulation
- Computation of 2-D cross section and level curves
- Volume and Surface analysis

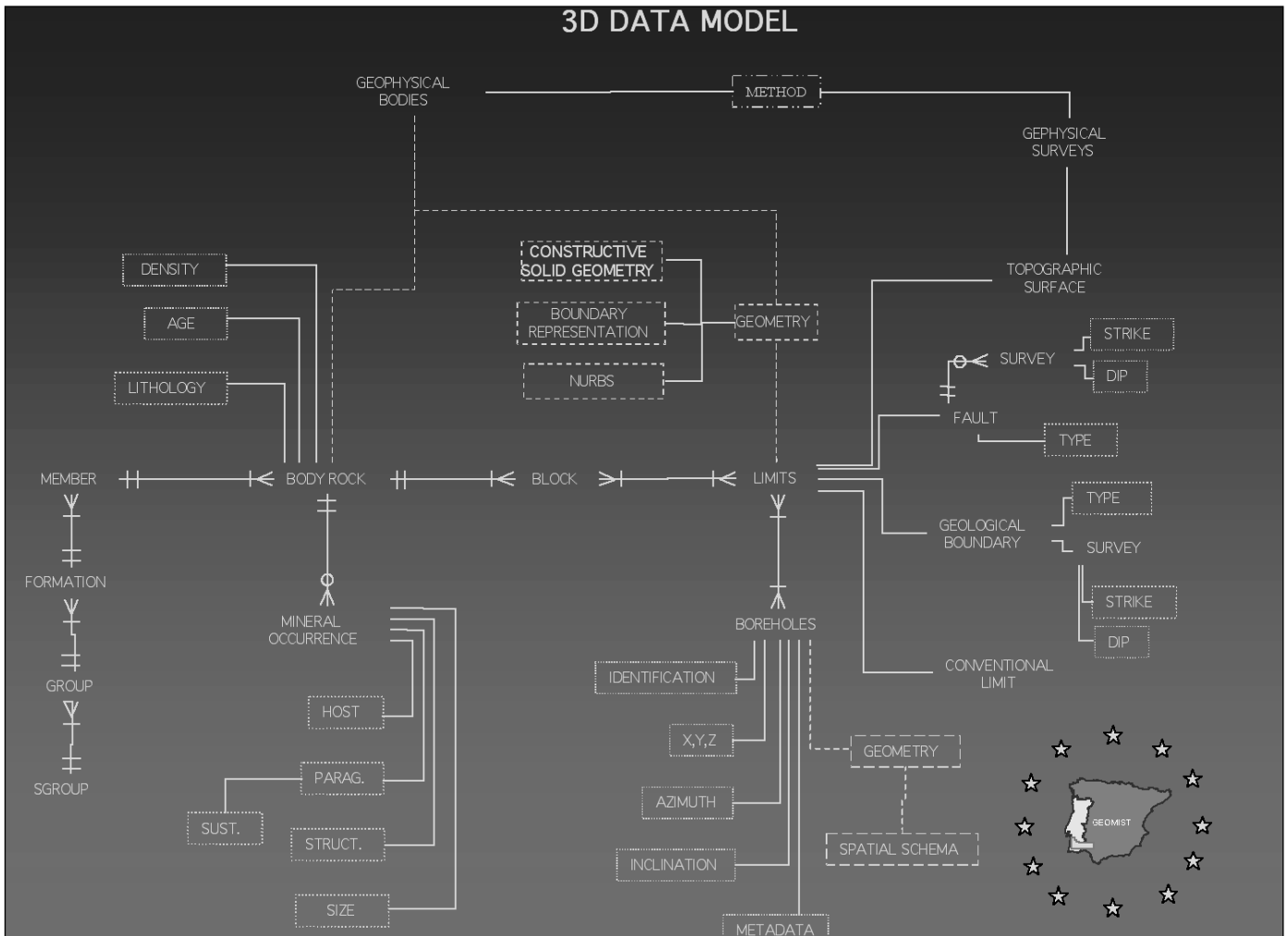


Fig. 3: 3D Data Model
 Fig. 3: Modelo de datos en 3D

- Information retrieval from graphical queries
- Generation of VRML files to visualise the 3-D model through the Web
- Projection of 2-D curves on surface
- 3-D dynamic cursor co-ordinate

Geomist Web server

The GEOMIST Web Service is based on web servers installed at IGME (Madrid) and IGM (Lisbon). The respective URL are:

<http://www.igme.es> (double click on "faja pirítica")
<http://geomist.igm.pt>

At home page the user can access directly to each partners homepage and to the GEOMIST services. A brief description of the project and on the

Iberian Pyrite Belt is also included. Three languages can be selected: Spanish, Portuguese and English.

The service architecture is based in the Client/Server model. A client program (Web browser) makes request to a server program. The navigation between the GEOMIST services is guided by a first menu with extended options forming new menus with the some properties. The server processes the request and return the information to the client. In the case of interactive services, the request are re-addressed to the specific server e.g. Geographics Information System (GIS) or Database Management System (DBMS).

The interactive services implemented into the GEOMIST Web include:

- Metadata Query

The GEIXS Metadata schema was adopted

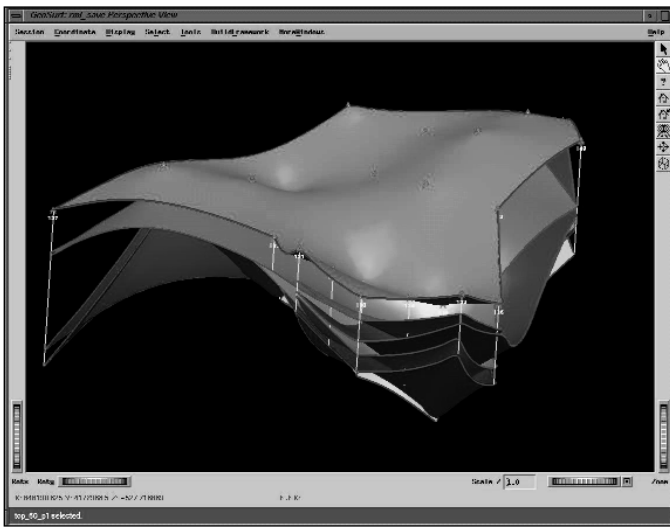


Fig. 4: VRML file of drill-hole data set
Fig. 4: Archivo VRML de datos de sondeos

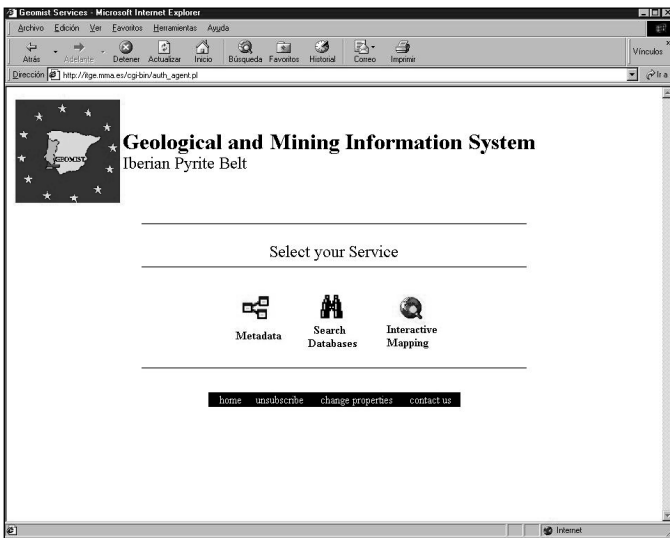


Fig. 5: GEOMIST Selection Service Web Page
Fig. 3: Página de selección de servicios

within GEOMIST, while the need to establish a tight connection between the metabase and the database administration lead us to develop an ORACLE based metadata entry application through an interface to the database management system which validates, stores and provides all the data. To insert and update data a Windows interface has been designed while queries to the metadata are made through a GEOMIST service in the Web environment.

- **Data Base Query**
The distribution of geographic data through the web is made in three steps:
 - First the access request is formulated and the security system checks the user identification and creates a new session according to the user access level, the server generates then a specific user and request interface access.
 - The server receives the request message, interprets the contents and get access to the DBMS
 - Finally the results are packed and returned back to the client in standards form.

To improve the user friendly characteristics, a number of JavaScripts programs were developed. Thus there is a function to pack the query components and send them to the server. The query results are sent back to the user, including a list of attributes with hyperlinks that display in detail the selected instance.

- **Interactive Map Server**
This service implements a set of functionalities to display maps according to certain parameters, such as scale, maps legend, map extent, etc... The map is served as an image which is displayed by the client browser. To manipulate the view (panning, zooming in or out, making visible or not some issues,...) new requests are sent to the server with new parameters that are processed by the server to generate a new map which is returned to the user.

GIS engines (ARC/INFO) are used to implement the interactive mapping services to collect, structure, edit, analyse and export the GIS data sets while ARCVIEW is used to display the GIS data sets as well as for communication with the web-server.

The basic architecture of the interactive mapping services is similar to the Client/Server model, where the client is a web browser and the server is a multi-tired server.

The implementation is based in the interaction and integration of distributed processes between the Web server, the GIS server and the Data Base server.

The security of the system is established in two levels, organisation level rejecting other access than to the hypertext protocol through firewall and gateway systems and GEOMIST security granting access to the GEOMIST restricted services through a user name and a password. Part of the metabases and all or part of the data are masked to the user, according to their user rights. The access to some services are restricted to authorised users at three different levels:

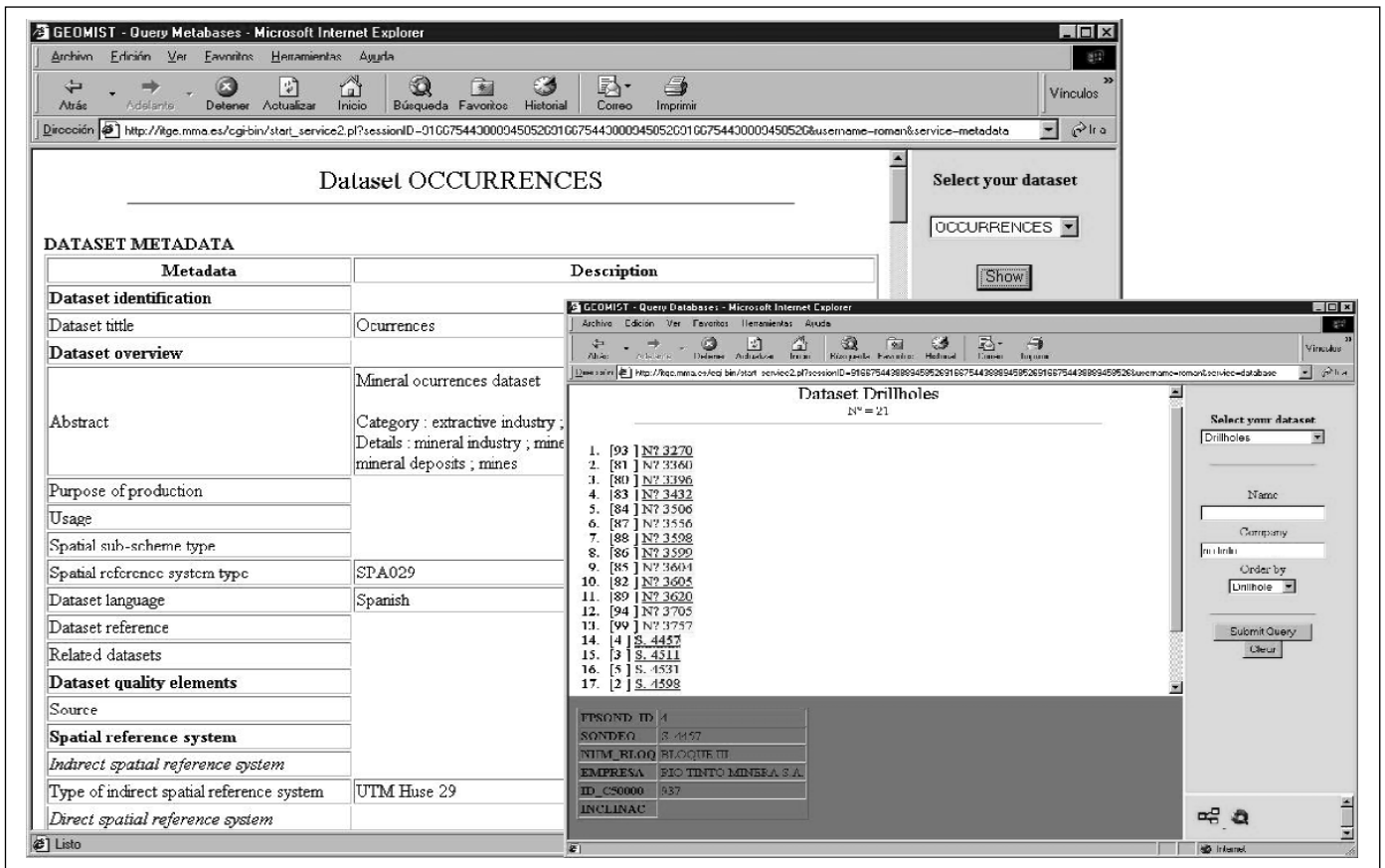


Fig. 6: Metadata and Data Base Query Result
 Fig. 6: Resultado de consulta a la metabase y a la base de datos

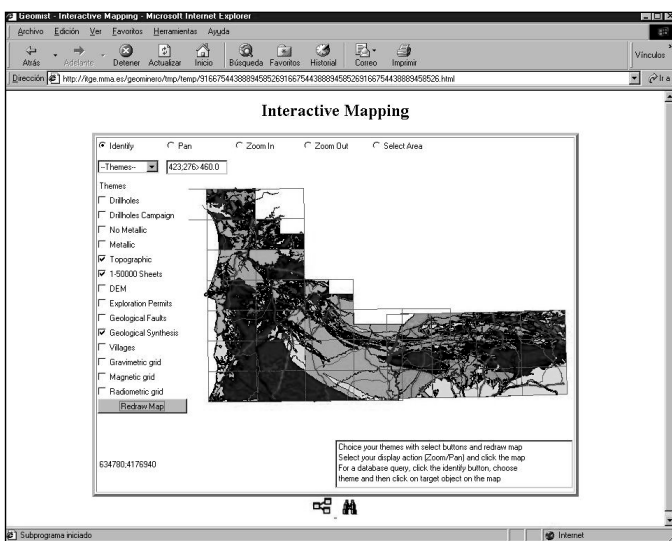


Fig. 7: Interactive Mapping Service Result
 Fig. 7: Resultado de servicio de mapas interactivos

1) free, 2) reserved and 3) confidential implemented in specific directories controlled by the Web Server with security protocols, i.e. Hypertext Transfer Protocol with Security (HTTPS).

The maintenance, updating and user access are based on the following criteria (Delgado, 1999):

- Identical data base structure in the Web Servers of IGME and IGM, including a unique Metabase on the whole information.
- Independent administration and updating of the data bases at the geodata level in Spain and Portugal, but common administration and updating of the Metabase.

With this approach the risks inherent to a common information management, i.e. data property, information integrity at the geodata level, query control to each institution, etc... are minimized.

- Unique user access through Internet to the GEOMIST Web Server on the Iberian Pyrite Belt. It will be transparent to the users if the requested information is located in Spain or Portugal. Unified

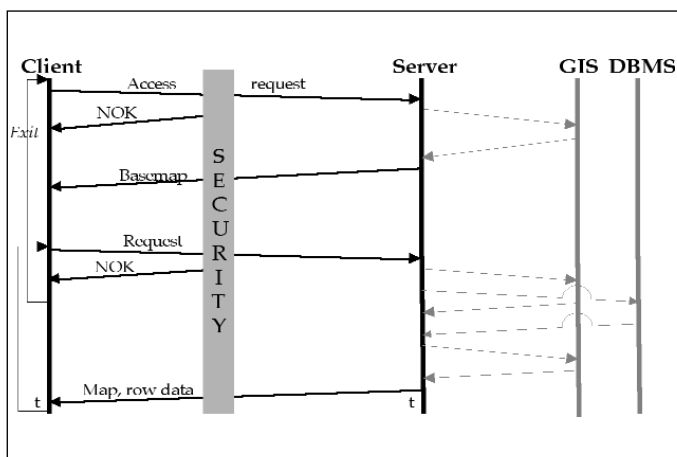


Fig. 8: Data Flow Interactive Map and Data Base Service
 Fig. 8: Flujo de datos del servicio interactivo de mapas y bases de datos

queries will allow to the users to get with an unique query the information requested that is available in both Servers.

- Common Metabase management, through common updating system (mirroring)
- Queries to the Metabase will be free while queries at the geodata level will be restricted to different users categories depending on the agreements between IGME, IGM, Junta de Andalucía and Mining companies.

Conclusion

The applicability of data base and GIS systems and Internet technologies to the management of mineral resources in a cross-border metallogenic area, has been demonstrated.

Active implication and feedback of both administrative bodies regulating the environmental aspects and mining permits delivery as well as private mining companies operating in the area has been very high and useful, proving the acceptability of this type of web based information system, giving a one stop shop for the geological and mining information in the area, reducing the information search costs before investment decisions are taken by the mining companies, and giving access to the administrative bodies to well structured and comprehensive information needed in the decision making processes.

The GEOMIST concept and tools, i.e. homogenisation and standardisation of cross-border geo-data sets and development of web based geological information systems can be applied to other sectors and cross-border areas.

Thus, the addition of new data sets or attributes derived from the geological data, such as permeability, geo-technical characteristics, geomorphology, geohazards, etc... can enlarge the application of this type of web based information systems to other sectors, such as environment, land use, civil protection, agriculture, tourism,...

Future plans have been agreed between IGME and IGM to add new data sets to GEOMIST as well as, to assure its continuity information system beyond the project completion in agreement with the regional bodies in Spain and Portugal and the private sector interested in specific sets of data.

In conclusion GEOMIST can be considered as the reference and driving force for the application of cross-border web based information systems, helping to define technical and policy plans in relation with geo-data normalisation issues at European levels and with the harmonisation of the data accessibility and data price policy in the different European countries.

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