INSPIRE data harmonisation of mineral resources: contribution of MINERALS4EU project

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Armonización de datos de recursos minerales INSPIRE: contribución del proyecto MINERALS4EU

Catarina Lopes[(1)], Lídia Quental[(1)], Daniel Oliveira[(1)], Augusto Filipe[(1)], Aurete Pereira[(2)]

Abstract

Georesources support society at different levels, depending on their technological development, and thus strongly impact on the economic, societal and environmental sustainability pillars. The European project MINERALS4EU [5] created the European Mineral knowledge Data platform (EU-MKDP [6]), to provide harmonised data related to mineral resources, as well as statistical related information, e.g., minerals yearbook. The nuclear pillars of the EU-MKDP architecture were based in the datamodels and harmonised terminology developed by INSPIRE and IUGS-CGI (represented by GeoSciML and EarthResourceML). The Portuguese input to this platform was based on mineral occurrences and resources information system, SIORMINP [15]. SIORMINP contains information of categorization of mineral potential, past concessions, commodities reserves and resources, and exploitation activity. The SIORMINP dataset was harmonised according to the MINERALS4EU project data model and vocabularies, and published using OGC compliant Web services in EU-MKDP. This work shows how the data harmonization was undertaken to integrate national database in the EU-MKDP, and more recently to improve the national geoportal to be INSPIRE compliant.

Resumen

Los recursos genéticos apoyan a la sociedad en diferentes niveles, dependiendo de su desarrollo tecnológico y, por lo tanto, tiene un gran impacto en la economía y la sociedad y en los pilares de sostenibilidad ambiental. El proyecto europeo MINERALS4EU [5] creó la Plataforma Europea de Datos de conocimiento Mineral (EU-MKDP [6]), para proporcionar datos armonizados relacionados con los recursos minerales, así como los relacionados con información estadística, por ejemplo, el anuario de minerales. Los pilares nucleares de la UE-MKDP se basaron en los modelos de datos y la terminología armonizada desarrollado por INSPIRE y IUGS-CGI (representado por GeoSciML y EarthResourceML). La contribución de los portugueses a esta plataforma se basó en el sistema de información mineral de ocurrencias y recursos, SIORMINP [15]. SIORMINP contiene información de categorización del potencial mineral, concesiones pasadas, reservas y recursos de materias primas, y actividad de explotación. El conjunto de datos de SIORMINP se armonizó de acuerdo con el modelo de datos del proyecto MINERALS4EU y vocabularios, y se publicaron utilizando servicios web compatibles con OGC en EU-MKDP. Este trabajo muestra cómo se llevó a cabo la armonización de datos para integrar bases de datos en el EU-MKDP, y más recientemente para mejorar el geoportal nacional para ser conforme con INSPIRE.

Palabras clave: mineral resources, SIORMINP, INSPIRE, data harmonisation, Minerals4EU.

Keywords: recursos minerales, SIORMINP, INSPIRE, armonización de datos, Minerals4EU.

[(1)]Laboratório Nacional de Energia e Geologia.
Departamento URMG
catas.lopes@gmail.com, lidia.quental@lneg.pt,
daniel.oliveira@lneg.pt, augusto.filipe@lneg.pt
[(2)]Laboratório Nacional de Energia e Geologia. Departamento Unidade de Informação Geocientífica
aurete.pereira@lneg.pt

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1. INTRODUCTION

Georesources, including raw materials, support society at different levels, depending on their technological development, and thus strongly impact on the economic, societal and environmental sustainability pillars. The raw materials European initiative (RMI, 2008) sets the guidelines to promote several integrated actions in order to access raw materials. These actions cooperate to improve the European mineral resources knowledge base in order to reduce the dependence from non-European countries and, simultaneously, the EU's consumption of primary raw materials, promoting an efficient use of the resources by the use of secondary raw-materials and recycling. To accomplish these goals, the stakeholder platform European Innovation Partnership on Raw Materials (EIP RM) was implemented and several projects were developed within the EU-FP7 and EU2020 financial programs, such as OneGeology-Europe, ProMine, EuroGeoSource, EURARE and InGeoClouds. Under the framework of the INSPIRE Directive, whose goal is the establishment of an Infrastructure for Spatial Information in the European Community, as well the EGDI-Scope project, the RMI and the Waste directive, the Minerals4EU project (Minerals intelligence network for Europe) had as main goal the development of a permanent minerals intelligence network for Europe (WP2) in order to supply data, information and knowledge related to mineral resources of the EU, giving a fundamental contribution to the EIP RM. With the purpose of sharing information and knowledge amongst the European Geological Services and other partners, the project developed the Minerals Knowledge Data Platform (the EUMKDP) and a web portal to provide geospatial harmonized data related to mineral resources across Europe (WP5), a European Minerals Yearbook with statistical information from each country (WP4) and foresight studies related to the access to mineral deposits, recycling and efficient use of the resource and zero waste (WP6). The EUMKDP allows the combination of information related to raw materials, specifically primary and secondary mineral resources and to provide end-users full access to complete information related to the whole mineral resources value chain, from primary sources to waste streams, from exploration to production and trade, from estimates of resource availability to foresight studies on raw materials supply and demand in the EU [1]. The EU-MKDP represents the first pan European raw materials knowledge base [2], constituting one of the first bricks of the European geological data infrastructure, in a period of time where the member states were taking the first steps towards the implementation of the INSPIRE Directive[1]. More recently the platform accommodated the extension for urban waste for the on-going H2020 ProSUM project.

The two year project was structured in six WPs and LNEG participated actively in 3 of them, namely in WP4, WP5 and WP6.

2. MINERALS4EU DATA PLATFORM

2.1. Minerals Knowledge Data Platform (EU-MKDP) – Data models

Regarding the EU-MKDP architecture, there are two major ongoing interoperability activities in Europe that represents the key pillars of the EU-MKDP architecture: 1- The geological community global data exchange standardization activities mainly represented by the GeoSciML [11] and the EarthResourceML [12] projects organized by the Commission from the International Union of Geological Sciences/Commission for the Management and Application of Geoscience Information (IUGS/CGI); and 2 – The European legislative/technical framework for building the Spatial Data Infrastructure in Europe (INSPIRE – http://inspire.ec.europa.eu/) that covers 34 spatial and environmental themes including geology and mineral resources[3]. Both activities EarthResourceML as well as GeoSciML are community developed exchange formats for providing detailed information on earth resources including mining wastes as a secondary resource and have served as the basis for the INSPIRE Geology / Mineral Resource core data models and have been used as well to extend it [3]. GeoSciML provides a standard data structure for common geologic features (e.g., geologic units, structures, earth materials) and artefacts of geological investigations (e.g., boreholes, specimens, measurements) and EarthResourceML is an XML-based data transfer standard for the exchange of digital information for mineral occurrences (e.g. geological characteristics and setting of mineral occurrences, commodities, reserve, resource and endowment), mines and mining activity (e.g. mining activity type, production of concentrates, refined products, and waste materials) [3].

INSPIRE data model for mineral resources (category 21, Annex III) is organised according to two major categories of information: (i) description and location of mines and mining activities and (ii) description and location of mineral resources, including its classification, ore measurements and commodities [14] (Figure1). Within the minerals4EU data model, this is the mandatory INSPIRE core model and integrates 19 distinct tables.

For the architecture of the EU-MKDP platform EarthResourceML and GeoSciML data models were used to enlarge the scope and detail of the INSPIRE core data model, thus covering additional requirements of the EU RMI and the Mining Waste Directive, as the location of waste deposits and assessment of waste material and related environmental risks, including the type -quantity and quality - of product resulting from the mining activity. Also, the Mineral Resources extension was developed to provide a broad description of rock (Earth material) and mineral products. Within the minerals4EU data model, these models form the EarthResourceML data model and INSPIRE extension and covers 15 distinct tables.

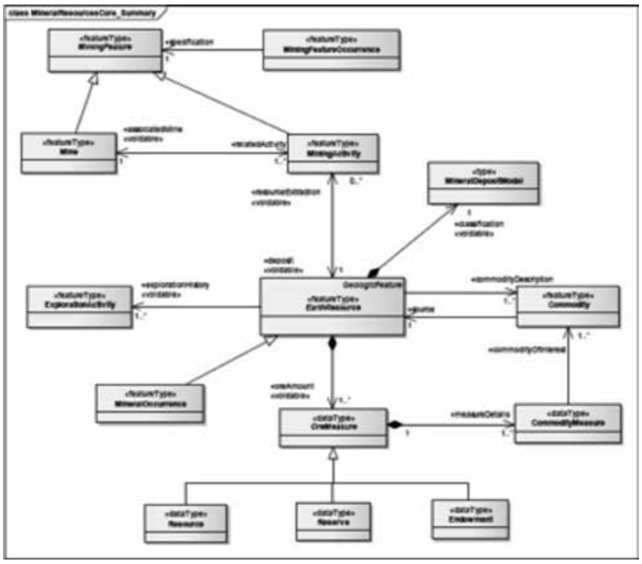

Figure1. Overview of the INSPIRE MineralResources core UML data model, based on EarthResourceML. Figure from INSPIRE Data Specification on Mineral Resources [14]

The Minerals4EU extensions covers 9 distinct tables and it was added to the model to allow additional information as remarks on mineral occurrences and mines.

2.2. Vocabularies or codelists of the EU-MKDP platform

Semantic interoperability was promoted through the use of controlled vocabularies from INSPIRE Core Data Models for Geology and Mineral Resources and EarthResourceML v.2.0 model embedded in the EU-MKDP data model [3]. Additionally, recommendations from the IUGS / CGI Geosciences Terminology Working Group (GTWG), results from previous projects namely EuroGeoSource and ProMine, Commission decision (2000/532/EC) on hazardous waste and possible alignment with the EU-FP7 EURARE project, were also considered [3]. Specifically there are: 14 codelists from INSPIRE/EarthResourceML; 8 codelists from EarthResourceML; 1 codelist from INSPIRE, 1 codelist from EarthResourceML/Census, 1 codelist from Commission decision, 1 codelist from IMA, 4 codelists from GeoSciML and 3 codelists from INSPIRE/ GeoSciML.

Following the INSPIRE specifications and the Minerals4EU line commands, all absent values must be classified into one of the possible categories - "Unknown", "Unpopulated" or "Withheld" - existing for that purpose specific fields within the data model.

2.3. Distributed system architecture

The Minerals4EU project developed an operational distributed data management system based on high-level interoperability standards founded on the advances made in former projects; namely within the ProMine project – specifically the collected data on primary and secondary resources and the contributions and improvements made to the INSPIRE Mineral Resources data model and the Earth Resource data model (ERML) - and the EuroGeoSource project - collected data and implementation of INSPIRE compliant distributed architecture - [10] with regards to database structure, harvesting systems, web services, metadata management, integration of non-structured information and cloud computing [1].

In detail, database model from EU-MKDP reuses entirely the structure implemented in the project EuroGeoSource, and improves it to be compatible with specifications of INSPIRE MR Version 3 data model and the ERML V 2 0 and related codelists, and expands it and makes it more complex to cover the waste mining information.

The EU-MKDP distributed architecture consists on a central harvesting database synchronized with a central diffusion database, as presented in the Figure 2.

This architecture can be divided in three major sections [1]: 1.The national level, from which each country provide data for the Harvesting System through a WFS. The database provided at this level is in PostGreSQL, which uses the M4EU data model with the codelists from INSPIRE. Data can be mapped to this database from the original database through an ETL (Extraction-Transformation- Loading) tool such as GeoKettle. The data is made available as a web service (WFS / WMS) compliant with INSPIRE specifications, created from Deegree3, which transforms relational data into GML: INSPIRE compatible featurecollections; 2. The central Harvesting System which regularly reads the data from the WFS of national level and stores it in the Harvesting Database. The data is subsequently delivered to the Diffusion System through a basic synchronization mechanism The Central Harvesting Database has a data model equal to the one from the national level database.; 3. The"Diffusion Database" is updated regularly with data from the "Harvesting Database". Having the same database structure, it is optimized for diffusion of the data and for the computation of requests to the services. The Figure 2 shows the UE-MKDP detailed architecture.

The Minerals4EU metadata catalog (http://m4eu.geology.cz/metadata/) is the central point for access metadata from European mineral resources and related issues. The catalog is based on the Micka system, which allows the user to work with spatial data metadata in accordance with international standards (ISO 19115 Geographic Information: Metadata, ISO 19119 Geographic Information: Services, ISO 19110 Geographic Information: Methodology for feature cataloging, ISO 15836: 2009 - Information and documentation - The Dublin Core metadata element set) and supports the distributed metadata management system (allows reusing existing metadata). The profile is compatible with INSPIRE Metadata Implementing rules: Technical Guidelines from 2013-10-29.

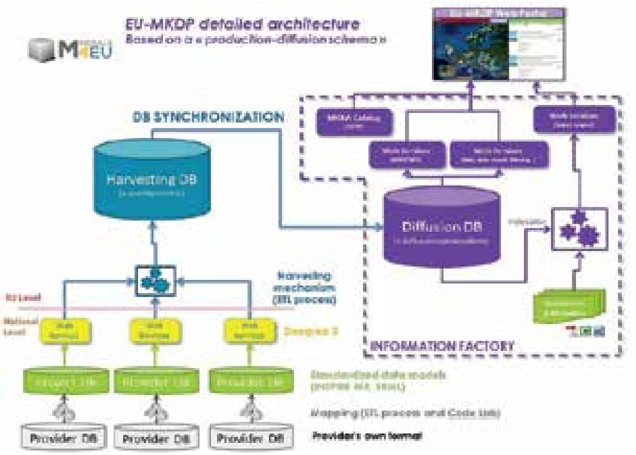

Figure 2. UE-MKDP architecture: a "Harvesting System", synchronisation process with "Diffusion System", an "Information Factory" and the indexation process for structured data and non- structured data. Available in Cassard [10]

3. PORTUGAL- DATA HARMONIZATION OF MINERAL RESOURCES

3.1. SIORMINP

The Portuguese input to this platform was based on the national mineral occurrences and resources information system, SIORMINP [15]. The SIORMINP contains geospatial information regarding categorization of mineral occurrences and resources, regional and local geology, mineralogy, past mining licenses and mining activity, and commodities. It was designed and created to broaden geoscientific, technical and economic knowledge on mineral occurrences, resources and reserves, by supplying information on mineral resources for geological maps; contributing for the mining development and its sustainability, specifically by selecting and diffusing information regarding areas with mineral extraction potential to exploration companies, supporting, as well, an efficient land use planning [9]. SIORMINP data has been stored in MS Access databases with its own design/architecture and vocabulary, based on a relational model in which each mineral occurrence or resource is connected to a wide set of auxiliary tables, each one containing data for a particular subject and related information[8]. Since 2005, the SIORMINP DB was integrated in the LNEG's geoportal (http://geoportal.lneg.pt/) [9].

3.2. Data harmonization

In the scope of EuroGeoSource (EGS) project [7] SIORMINP data was transformed according to general rules set by the INSPIRE Directive specifications as well as the EGS datamodel, and published using OGC compliant Web services [8]. More recently, within the Minerals4EU project this dataset was improved and harmonised according to the project data model and specifications, and published as WFS. For the sequence of steps required to transform national data from a local database into the M4EU relational database model, the project conceived the use of ETL technology, i.e. Extraction of data from the local database, transformation of the data according to the harmonised data model and mapping data into the relational database, applying proper software as GeoKettle. However, in the Portuguese case, the process undertaken turned out to be semi-manual as will be described below.

The first step was the detailed analysis of the Minerals4EU datamodel, in order to understand the needed information and define the data available to fulfil the model. The model was conceived taking into consideration the former European-funded mineral resources INSPIRE projects, EGS and ProMine, in which LNEG participated and helped in further developments. The following step was to identify which fields in the Minerals4EU data model could be fulfilled using the information already classified according to INSPIRE data specifications within the former projects based on SIORMINP. Three distinct situations were identified: i) a complete match between INSPIRE codelists - no need for further reclassification; ii) a partial match - partial need for reclassification; iii) no match with CGI codelists - need for reclassification. Given the specificities and requirements of the data model, concerning genetic and geological settings, data reclassification had to be done by the mineral resource experts. In addition, based on available data in the SIORMINP, a fourth situation was considered to be done by the experts: iv) classification of "new" data.

To achieve these goals, some excel files were distributed - by groups of substances - to the mineral resource experts. These files indicated which fields were to be filled in, which codelists should be used and contained some guidelines according to the project specifications. These files had already been created for the EGS project and have been improved, updated and adapted to the Minerals4EU model. An internal meeting preceded the files distribution. A schematic illustration of the presentation at the internal meeting is presented in Figure 3.

In detail, the following figures show the tables from the Minerals4EU fulfilled by the Portuguese data, the origin of the data, and reclassification scheme, while used. In some cases, data is directly translated from SIORMINP with no need for reclassification.

Mineralocurrence table (Figure 4) stands out as the main nuclear table. It aggregates information related with mineral occurrences, as the type, geometry, name, etc. The field "origem dos dados" indicates – only for the fields with data - the origin of the data. Specifically in the "occurrencetype", it is indicated the relation with SIORMINP classification. The long size of the table is the reflex of the several connections with other tables containing information about dimension, form, planar and linear orientations, related documentation and geological history, as illustrated in Figure 5. All these tables were partially or totally (re)classified.

Geometry is represented at the occurrence level in the table "mineraloccurrence" and at mining level, within the table "miningfeatureoccurrence". The geometry corresponds to the points of the national inventory of SIORMINP, which in turn represent - in most of the cases- the centroid of the mining concession areas. The reference system used for spatial information is SRID 4258, which corresponds to ETRS 89, converted into the BLOB binary code, for PostGIS.

Due to some limitations in the mining codelists, specifically not embracing hybrid classifications, there were several duplications in the "miningfeatureoccurrence" to assure a complete and objective description of the Portuguese mining activity. The most flagrant example is the most typical Portuguese open-sky and underground mining activity that must be represented by one point for open-sky mining and another point for underground mining. Another reason for the geometry duplication is related with some constraints within "miningactivity", "mine" and "Miningwaste" that require the "miningfeatureoccurrence" identifier to be unique. For those two conditions to be met, it means that a "miningfeatureoccurrence" had to be created, i.e., a geometric point, for each type of mining activity, another geometric point for the mine and another one for each related miningwaste, etc

The Figure 6 shows the relation between Mining tables and indicates the origin of data in relation to the SIORMINP and the former projects ProMine and EGS.

The "oremeasure" table provides information on the classification method, the ore calculations and the body size of the ore. It is linked to the "reserve" and "resource" tables. The commodity table has information on the importance and rank of the commodity. Figure 7 shows the relationship between these tables, their link to the "mineraloccurrence" table, and the identification of data source and relationship to the preceding classifications. The SIORMINP uses the UNFC classification from 1997.

Another part of the model is centred on "earthresourcematerial" - "earthmaterial", and contains information about the

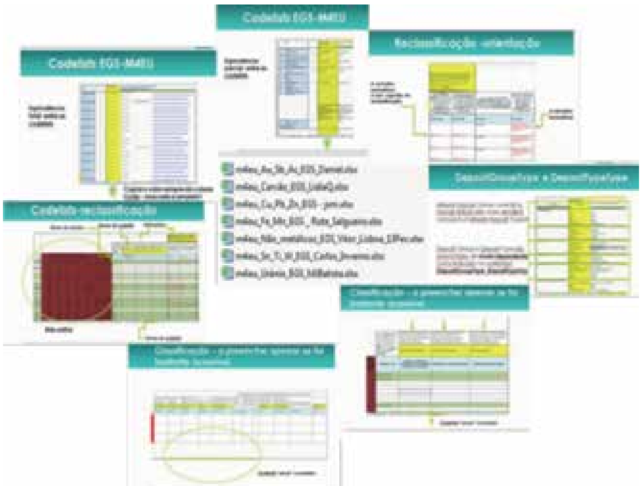

Figure 3. Schematic illustration of the presentation at the internal meeting. The A, B, C and D situations are represented in this scheme. In the centre, are the seven files distributed for reclassification

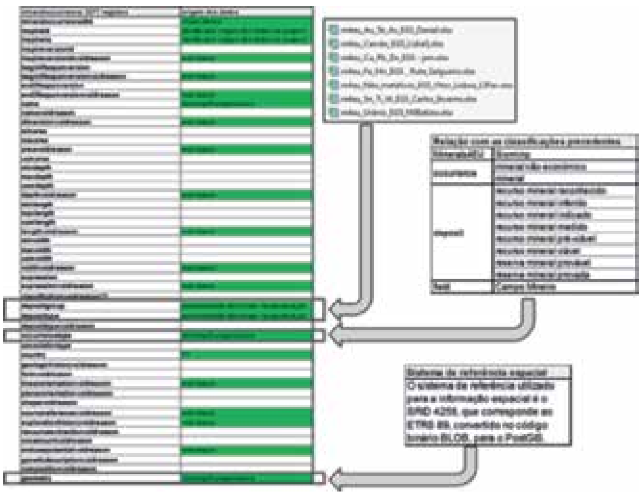

Figure 4. Mineraloccurrence table and its relation with data origin. The fields indicated were reclassified from the xls files and previous classification. Relation with previous classifications

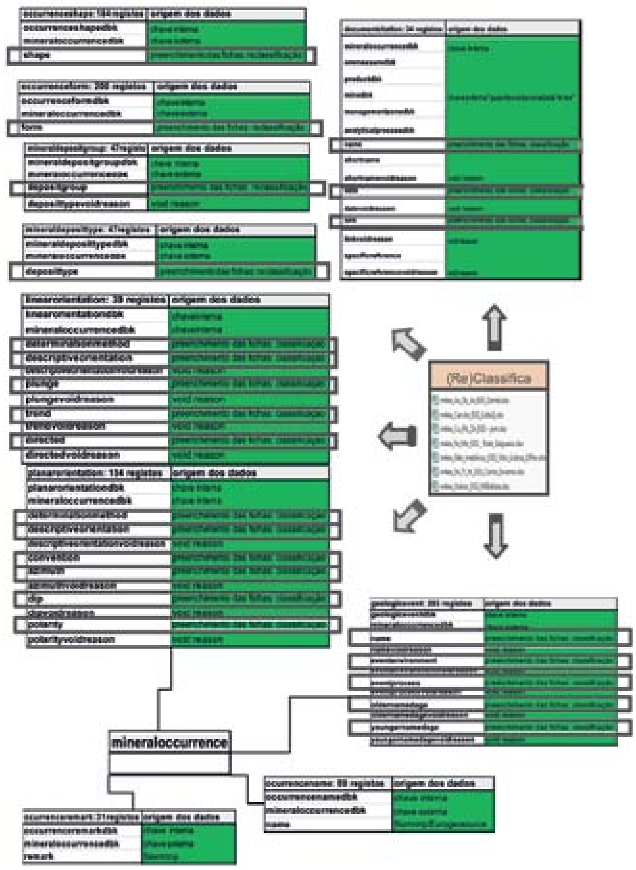

Figure 5. Tables related to Mineraloccurrence with indication of data origin in relation to the SIORMINP and the former projects ProMine and EGS

rocks and minerals associated with the mineral occurrence (Figure 8 and Figure 9). For each mineral occurrence the "ore", the "gang", the "hostrock" and the "alteration product" of the "hostrock" are characterised. In the "codelist" from IMA no option representing "mineral groups" was available. As this is widely used in our data, a forced solution had to be found to overcome this limitation. The situations and respective solutions found were: tourmaline (schrol); Feldspar (albite); Apatite (fluorapatite); Mica (muscovite); Chlorite (clinochlore); Amphibole (ferrohornblende) and carbonates (calcite).

The other part of the model covers the requirements of the Raw Materials Initiative and the Mining

Waste Directive. These requirements specifically include the location of the mining wastes and the evaluation of the waste material and related environmental risks. This information is centred on the "miningwaste" table, which is associated to the "mining activity" table (Figure 6). The "miningwaste" table includes information on the storage, material, type of waste and associated environmental impact and related geometry (from the "miningfeatureoccurrence" table). For this part of the model we used part of the information from Promine project and we integrate it in the "miningwaste" model, namely as "wastetype", "Wastestoragetype "and" environmentalimpact "(Figure 10).

Additionally, "new information" regarding the "wastetype" was identified based on the preliminary diagnostic reports of abandoned mines. Centred on this analysis a classification of the "wastes" according to the "codelists" of

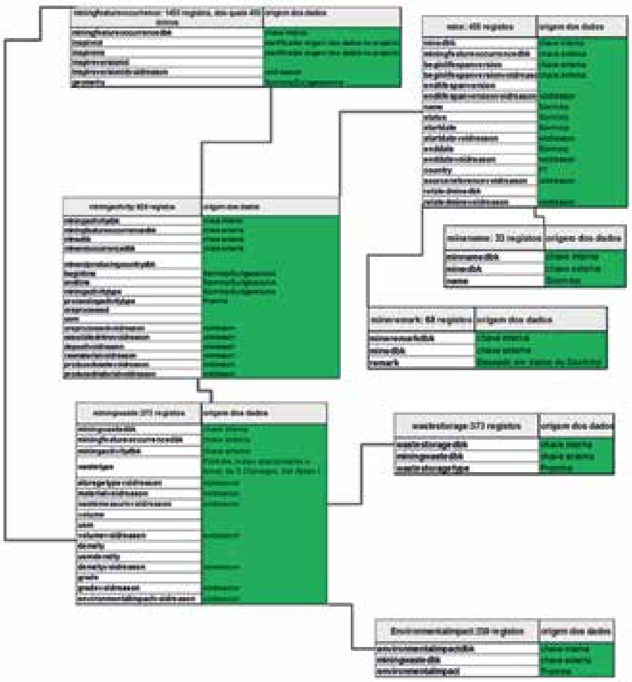

Figure 6. Tables "mine", "miningactivity", miningfeatureoccurrence", "mineremark" and "miningwaste" Indication of relation between data, SIORMINP and the former projects ProMine and EGS

the model was prepared.

3.3. Portugal -M4EU (INSPIRE compliant) Web Feature Service implementation

In order to implement the service, a virtual machine was created, – lnegmineral4eu.lneg.pt - and the software stack installed following the cookbook from the project which described all the steps required. The software stack consisted of a number of existing open source components – the object relational database management system PostgreSQL to implement the relational database; spatial objects support from PostGIS, webserver and servlet container Apache Tomcat and

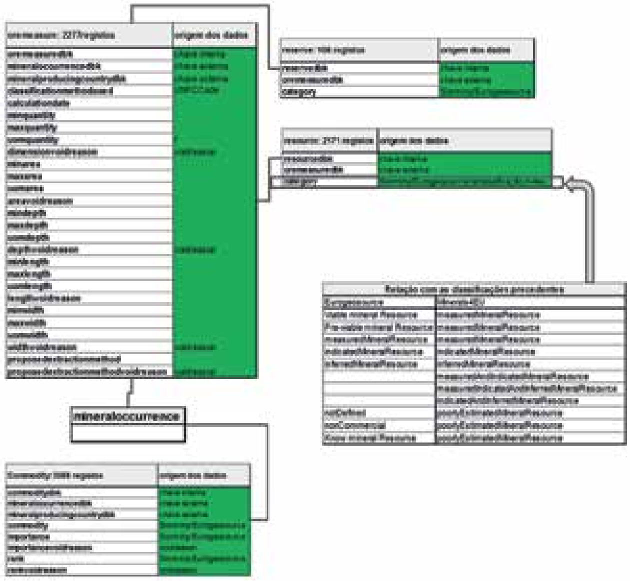

Figure 7. Tables "oremeasure", "resource", "reserve" and "commodity". Connection to the table "mineraloccurrence". Data source identification and relationship to the preceding classifications

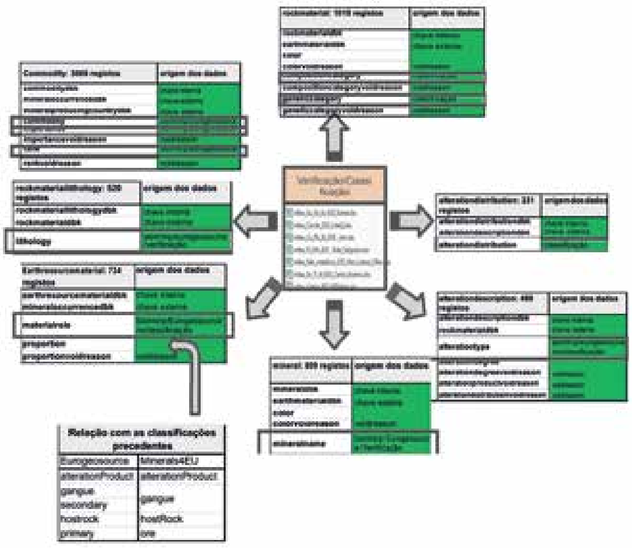

Figure 8. "Earthresourcematerial" and related tables. Data source identification and relationship to the preceding classifications

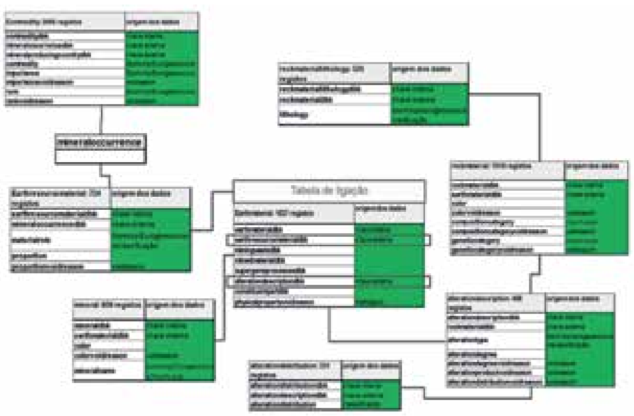

Figure 9. Relashionship between"earthresourcematerial" and "earthmaterial"

Deegree to implement the WFS- and some SQL script files to configure those components, defining the Minerals4EU relational database model as tables, views and codelists containing PostGIS specific features. Also, the Degree Minerals4EU mapping file which describes how database tables are transformed to Minerals4EU GML.

Loading data into the PostgreSQL Relational Database was made using SQL scripts after compilation of all xls tables with the transformed data.

4. FINAL CONSIDERATIONS

In the scope of EuroGeoSource (EGS) project [7] data from SIORMINP was transformed according to general rules set by the INSPIRE Directive specifications as well as the EGS datamodel, and published using OGC compliant Web services [8]. More recently, within the Minerals4EU project this dataset was improved and harmonised according to the project data model and specifications and published as WFS. However, these transformed and harmonised dataset were kept in virtual machines, serving the data for the EGS and the Minerals4EU projects within the respective datamodels and specifications. Presently some actions are being undertaken in order to make this harmonised dataset available in LNEG's web portal, representing the Mineral Resources INSPIRE-compliant dataset. Within these actions, the harmonised dataset from Minerals4EU project have been loaded into an ESRI INSPIRE-compliant geodatabase and will be published in the LNEG Portal in the near future.

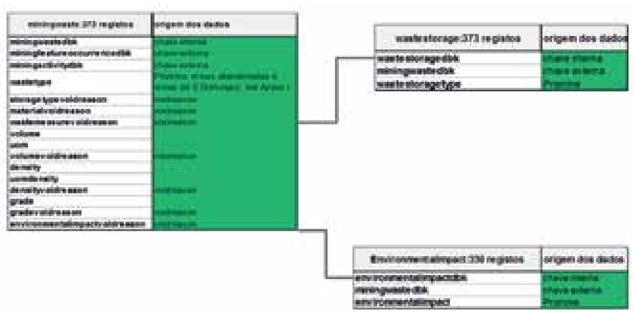

Figure 10. "Miningwaste", "wastestorage" and "environmentalimpact". Data source identification and relationship to the preceding classifications

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Sobre los autores

Catarina Lopes

Holds a University degree in Applied Geology and Environment from the Faculty of Science from Lisbon University and a M.sc in Geographic Information System (GIS) from Thecnical Institute from Lisbon University. She developed the thesis in statistical and spatial analysis of the distribution pattern of geochemical data and biomonitors. Additionally she did a course in GIS in former Superior Formation Institute (IFQ) and more recently in PostGIS Spatial Databases and in Spatial Data Infrastructures (IDE) and Web Mapping, both from the Polytechnic University of Valencia. Her field of expertise is in GIS applied to geoscience, statistical and spatial analysis and databases. She worked for eight years in private companies as a GIS Technician and since 2011 she has been working in several international and national projects within project fellowships. Within this work, she designed and implemented a Geochronological database; applied multivariate statistical analysis methodologies to lipid biomarkers; she harmonized and implemented information from the National Mineral Occurrences and Resources Information System - SIORMINP in INSPIRE compliant structured and harmonized data models. Currently she collaborates in the development of a methodology for the definition of a Mineral Deposit of Public Importance.

Lídia Quental

Is a senior geologist at the National Laboratory for Energy and Geology (LNEG), holds a M.Sc. in Geo-Resources and a Ph.D. in Engineering Science both from the Technical University of Lisbon. She is a remote sensing expert using multi-source data and methodologies to improve knowledge in thematic areas of geosciences. She participates in several EU and transnational R&D projects related to raw materials, digital platforms and environmental risk assessment related to mining areas. She collaborated in foresight studies as well as in identification of stakeholders for digital platforms related to raw materials. She is a member of the Earth Observation and Geohazards Expert Group of EuroGeoSurveys and is the Portuguese delegate to the Copernicus (European Space Program) User Forum. She is currently the Head of Geoscientifc Information Research Unit in LNEG.

Daniel P. S. de Oliveira

Holds a Ph.D. in Economic Geology from the University of the Witwatersrand (Rep. of South Africa) and a Ph.D. in Geology from the Faculty of Science of the University of Lisbon (Portugal). His area of specialty is the metallogenesis and petrography of mineral deposits. Additionally he works in geochronology, geochemistry and geological mapping, critical raw materials for Europe, Rare Earth elements and has been involved as a consultant in policy-making at European level. He has coordinated and participated in a number of national and international projects. He is currently the Head of the Mineral Resources and Geophysics Research Unit in LNEG and the Chair of the Mineral Resources Expert Group of EuroGeoSurveys.

Augusto Bento Filipe

Holds a Degree in Mining Engineering by the University of Coimbra (Portugal) and a Post Graduate in Georesources by the Instituto Superior Técnico - IST (Portugal). His area of specialty is in characterization, management and promotion of portuguese mineral resources. He has been involved in the Creation and development of DBMS, management of mineral resources in GIS (highlight to the DBMS SIORMINP - Information System of Portuguese Occurrences and Mineral Resources). He also contributes for the territory management (PDMs and PROts). He had provided mineral resources information to some European projects: Inspire, Promine, Eurogeosource, Minerals4EU and Minatura 2020.

Aurete Pereira

Is a geologist working at the Geoscientific Information Unit in LNEG. She graduated in geology from the Faculty of Sciences, University of Porto, and holds a MSc in Science & GIS from the Nova Information Management School, University of Lisbon. She won the CEN/TC 287 Award for Excellence in INSPIRE 2013 with her work in implementing the INSPIRE Geology Data Model in Geological Map Production in Portugal. Currently, she coordinates the INSPIRE-LNEG working group. Her area of specialty is information management and digital geological map production. She has participated in a number of national and international projects.