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## MINING CARTOGRAPHY IN SPAIN

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### Abstract

One of the most important points in the mining activity is the control of the exploitation carried out up to date in order to guarantee safety and correct rescue actions in the first place, and in relation to the actions of the development of work, relations between underground work with the outside and know how they affect each other, without a doubt the essential tools to carry out these tasks correctly are the plans and maps.

## KARTOGRAFIA GÓRNICZA W HISZPANII

**Słowa kluczowe:** kartografia w Hiszpanii, dyrektywa INSPIRE, projekt górniczy, mapy

### Abstrakt

Jednym z najważniejszych zadań w działalności górniczej jest kontrola prowadzonej eksploatacji, przede wszystkim w celu zagwarantowania bezpieczeństwa i właściwego prowadzenia akcji ratunkowych. Istotny element stanowią także działania dotyczące przebiegu eksploatacji oraz związki pomiędzy pracami podziemnymi i powierzchnią oraz ich wzajemne oddziaływanie. Bez wątpienia ważnymi narzędziami do poprawnej realizacji wymienionych zadań są plany i mapy.

## 1. INTRODUCTION

In each of the phases of the mining project is essential knowledge and control of the land, in terms of size, formation, and composition. This information will initially define the characterization of the mining exploitation and from it the evolution will be developed with all the changes that the different tasks and phases of the mining activity will leave on the ground (Fernández L. 1989). The control tool of these processes is the cartography, thanks to it, the graphic control of measurements and transformed data during the process is carried out. These tasks are carried out both in Spain and other countries of the European Union (Biegun D., Krawczyk A. 2016, Sokoła-Szewioła V., Poniewiera M.

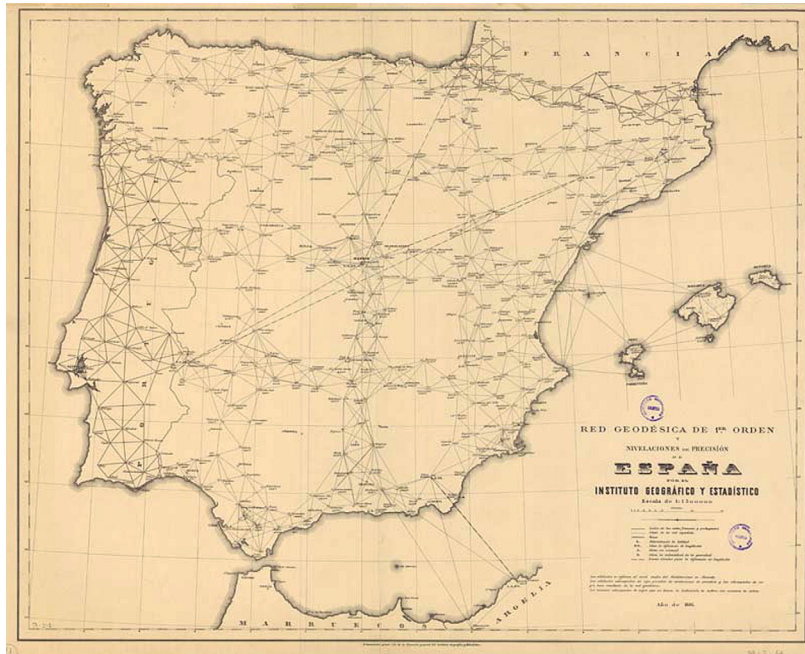
2017), mainly with the use of numerical elaborations in the GIS class systems.

In order to comply with European directives regarding public access to information related to spatial data infrastructures, in Spain there are two state institutes that make available cartographic information and thematic cartography of the country to all interested parties.

## 2. NATIONAL GEOGRAPHIC INSTITUTE (IGN)

The National Geographic Institute (Instituto Geográfico Nacional IGN) (<http://www.ign.es/web/ign/portal>) was created on September 12, 1870, administrative-





**Fig. 1.** Spanish geodesic network from 1886

**Rys. 1.** Hiszpańska osnowa geodezyjna w roku 1886

ly depending on the Statistics Department of the Ministry of Development, but with full freedom to exercise the technical faculties attributed to it, consisting of “the determination of the shape and dimensions of the Earth, geodesic triangulations of different orders, precision leveling, topographic triangulation, topography of the map and the cadastre, and determination and conservation of international types of weights and measures” (Martín López J., 2002). The first geodesic network map of Spain dates from 1886 (fig. 1).

From that moment until today the institute has been changing its functions until the body called the Higher Geographical Council is created, which is given an organic structure regulated by law and with specific functions.

The IGN is the center responsible for homogenizing the information produced by the different agencies in charge of generating the cartographic information, so that in this way it is coherent, it has continuity and there is interoperability of all geographic information about the national territory, collection, storage, treatment and dissemination of information, favoring the competitiveness of the private cartographic sector.

In order to do all this work, the institute carries out official cartographic production plans and programs, of-

ficial and standardized place names, spatial data infrastructures based on official geographic information. The national cartographic plans are triennial, which includes the current situation of cartography in Spain, applicable regulations, data policy and protocols for access to information and the conclusions of the previous plan as a starting point for the following work, from which they will set objectives, needs, indicators and costs of the new plan. All this information is available to the public through the Internet.

Likewise, IGN is the agency in charge of complying with the directive 2007/2/CE and through its national development laws managing all this information. The data is grouped into three large blocks, following the structure of the INSPIRE directive:

- a) Reference geographic information where is defined the National Geographic Reference Equipment: The Geodesic Reference System ETRS89 (fig. 2). The Official System of Coordinates, of which both the geographical coordinates that make it possible to unequivocally reference geographic information in space as a series of coordinates (latitude, longitude and height), as well as the flat coordinates of the UTM Projection System are part, in scales great-



**Fig. 2.** Spanish geodesic network nowadays

**Rys. 2.** Osnowa geodezyjna w Hiszpanii, obecnie

er than 1: 500 000, or that allows to univocally reference geographical information in space as a series of coordinates (x, y, z), in both cases based on the Geodetic Reference System.

The geographical organization of the country, as well as the administrative part, transport networks, protected areas and the publichydraulic domain is defined in this group too.

#### b) Fundamental thematic data

In this group of information are collected data related to specific topics more detailed in each area such a unit for the dissemination or use of statistical information. Buildings, through their geographical location and geometric shape, Soil and subsoil, characterized according to their depth, texture, structure and content of particles and organic material, stoniness, erosion and, where ap-

propriate, average slope and estimated water storage capacity. Land uses, public utility services, Human health and safety.

Atmospheric physical conditions. Geographical data are included based on measurements, models or a combination of both, as well as measurement sites (fig. 3).

#### c) General thematic data

The General Thematic Data include the data included in thematic cartography that, not being constituted by Fundamental Thematic Data, singles out or develops some specific aspect of the information contained therein or incorporates specific additional information. In any case, it is considered geographic information corresponding to General Thematic Data that is not related in the previous groups and contained in the following types of cartography:

Military, Forestry or agriculture, which collects information on the structure of forest vegetation or agricultural crops, as well as their primary uses, and on the potential or aptitude of the land for these uses.

Urban planning, which includes the geo-referenced information contained in urban and territorial planning instruments.

### 3. THE GEOLOGICAL SURVEY OF SPAIN

The Geological Survey of Spain (<http://www.igme.es/>) (Instituto Geológico y Minero de España – IGME) was created in July 1849 with the original denomination of “Commission for the Geological Chart of Madrid and the Kingdom”. Today IGME is a self-governing Public Research Institution attached to the Ministry of Economy and Competitiveness. It was the first center created in Spain for the study of the geology of Spanish territory, the formation of the National Geological Map, the recognition of mineral deposits and the study of groundwater. It has an essential role in the knowledge of natural resources and territory, covering areas of science and technology that are not covered by other institutions, and providing a continuous service to public administrations and society in general.

The functions of this service are:

- Studies, analysis and research in the field of Earth Sciences and Technologies.



**Fig. 3.** Map of polluting focus in Spain

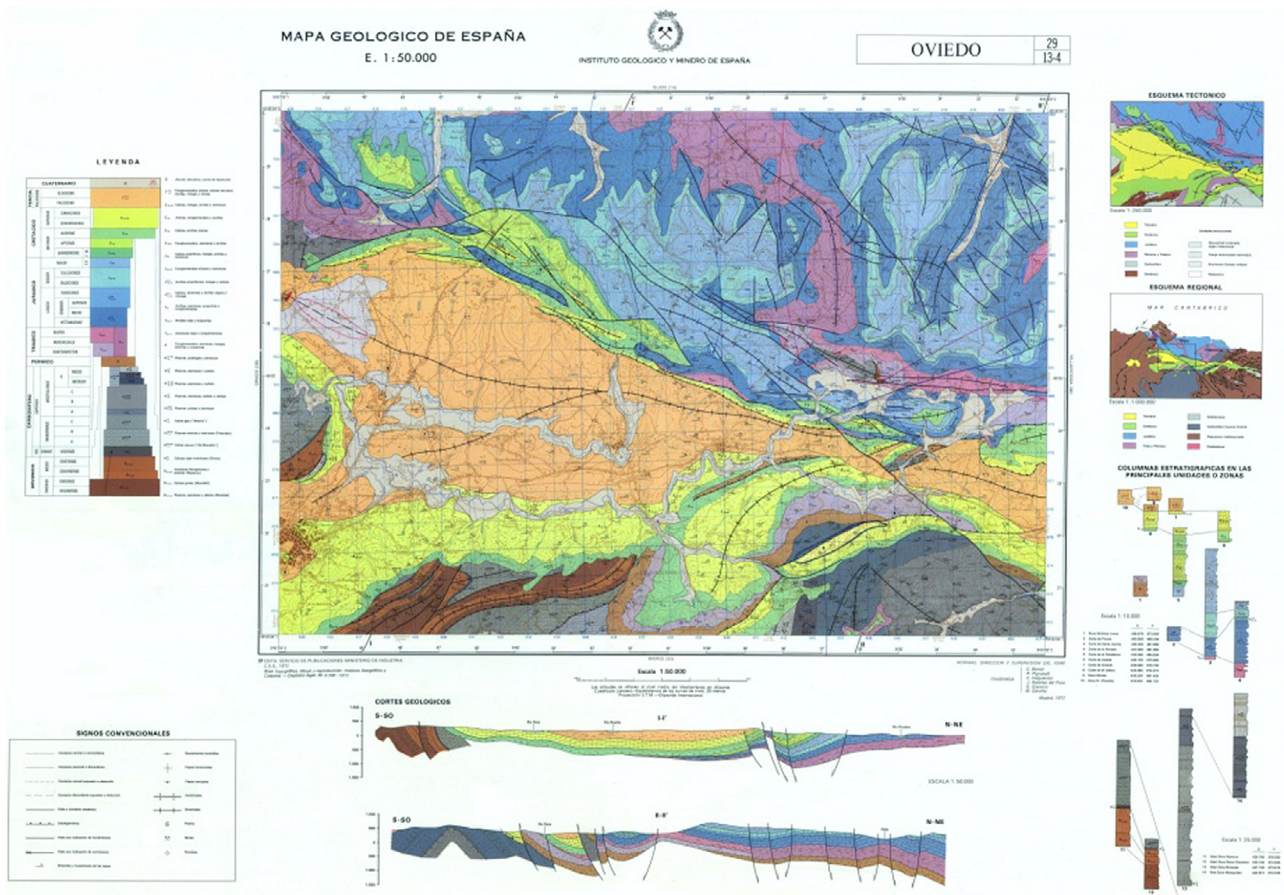
**Rys. 3.** Mapa źródeł zanieczyszczeń w Hiszpanii

- Generation of basic scientific knowledge.
- Information, technical-scientific assistance and advice to public administrations, economic agents and society in general, concerning geology, hydrogeology, geoenvironmental sciences, geological resources and minerals.
- Interdisciplinary relations with other areas of knowledge, contributing to the best understanding of the territory and of the processes that form and modify it, to the sustainable use of its resources and the conservation of the geological and hydrogeological heritage.
- Preparing and implementing budgets of R&D&I and knowledge infrastructures in national and international programs, within the scope of its competences.

The geoscientific cartographic activity is a basic reference of the IGME activity. The incorporation of

new geospatial information systems technologies in recent years allows associating georeferenced databases with basic geological cartography and producing cartographic documents, both systematic and at the request of the user. The main lines of action that guide the development of the IGOS geoscientific cartography are: the updating of the National Geological Map, MAGNA; the GEODE Plan for continuous geological mapping; the geological cartography of the continental shelf, GEODMAR Plan; geomorphological cartography and active processes; the geological risk cartography PRIGEO Plan; the mapping of mineral resources (maps of industrial rocks and minerals, metallogenetic maps); the hydrogeological cartography, and others (geochemistry, geophysics, soils, etc.).

The National Geological Map (MAGNA), made between 1972 and 2003 by the Geological and Mining Institute of Spain is distributed in 1: 50 000 sheets



**Fig. 4.** Map of the region of Oviedo at 1: 50000 scale

**Rys. 4.** Mapa rejonu Oviedo w skali 1: 50 000

(1: 25 000 in the particular cases of the Canary Islands, Ibiza-Formentera, Menorca, Ceuta and Melilla). The Geological Map shows the nature of the materials (rocks and sediments) that appear on the Earth's surface, their spatial distribution and the geometric relationships between the different cartographic units.

A geological cartographic unit is the grouping of one or more lithologies with a common age range, which has representation on the map at a defined scale or resolution. Each cartographic unit, as well as the different geological structures, are represented on the map with their own symbols. The representation of these units on the topographic base of the map, provides certain three-dimensional information that is completed with other geological data such as geological sections, stratigraphic profiles, soundings, etc. The map legend is a pictogram that represents the spatial relationship of the different cartographic units (chronology, superposition, geometric relation, lateral changes of facies, etc.). It also includes structural, hydrogeological and geological location diagrams of the leaf within its regional scope. Continuous digital geological mapping at 1: 50 000 scale generated specifically from the national topographic map 1: 25 000 of the IGN. There are geological and topographic maps of the different regions of the country and at different scales (fig. 4).

Regarding thematic cartography, it is based on geological cartography, shows the relation between relief and geology, distinguishes certain properties of rocks or shows the distribution of certain geological resources.

The geomorphological map Scale 1: 50 000, is a cartography based on the genetic interpretation of the recent landscape and oriented to the planning of the territory and environmental management. This map provides structured and accurate information on surface deposits and landforms. His legend, inspired by the geological map, has a double entry: morphogenetic and chronological. The elements of the map receive a color based on their morphogenetic assignment. The forms, erosive and depositional are represented on the map by symbols and plots whose color is dictated by their morphogenesis. The deposits or superficial formations, which provide lithological information, are expressed through enclosures of different color according to their chronology, within a range assigned by the genetic criterion.

Map with the characterization of the territory against the discharge of solid urban waste that may be a source of contamination of aquifers, distinguishing three cat-

egories: unfavorable zones, zones that require complementary studies and favorable zones. Included are landfills inventoried at the time of the preparation of the cartography, the catchment points for the supply. Scale 1: 50 000

Geotechnical and Geological Risk Maps aimed at studying specific areas at scales ranging from 1: 25 000 to 1: 5000. Normally they contemplate study the scope of a municipal term and in more detail in the urban helmet and its area of expansion.

Geological map of the continental margin and adjacent areas E 1: 200 000 consist in marine mapping of the Spanish continental shelf.

Geotechnical Map of Territorial and Urban Planning 1: 100 000, consists in the zoning of the territory in areas of more or less homogeneous geotechnical behavior (geotechnical units) that, for geotechnical reconnaissance planning purposes, will have a similar treatment.

Hydrogeological map of Spain at a scale of 1: 200 000, it is a map with the chronolithostratigraphic units differentiated according to their hydrogeological characteristics divided into impermeable and permeable distinguished by colors and frames that serves as the basis for the representation of divisions of surface and underground basins, underground flow directions, upwellings and control points. The main map also contains several 1: 500 000 scale schemes with exclusively hydrogeological information. The complementary information, which is normally included in another sheet, is made up of maps of aquifer systems, chemical quality, sources of contamination, crops and consumption, graphs of evolution and distribution of ions.

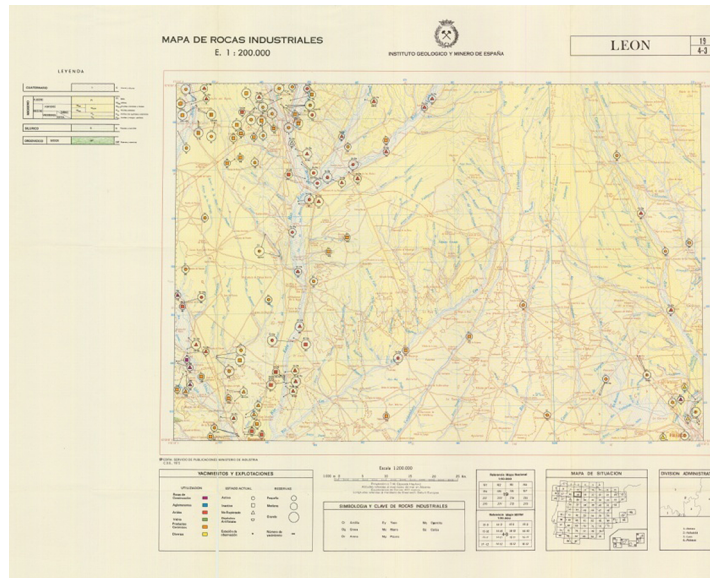
The Metalogenetic Map 1: 200 000 represents, on a simplified topographic and geological double base, the known mineral deposits or indices. It provides information about the mineral resource in question in each case (metallic, non-metallic minerals or energy resources), as well as its morphology and volume. In addition, it analyzes the origin of the signs, in order to deduce the geological features (fractures, stratigraphic levels) that determine their location. This series begins to be made from 1994.

Industrial Rocks Map at a scale of 1: 200 000 (old series) (fig. 5). Spatial distribution of deposits and exploitations of rocks and industrial minerals on a simplified geological basis and adapted to the objectives of the map the deposits and farms are represented by symbols that includes the use of the resource, the state of the

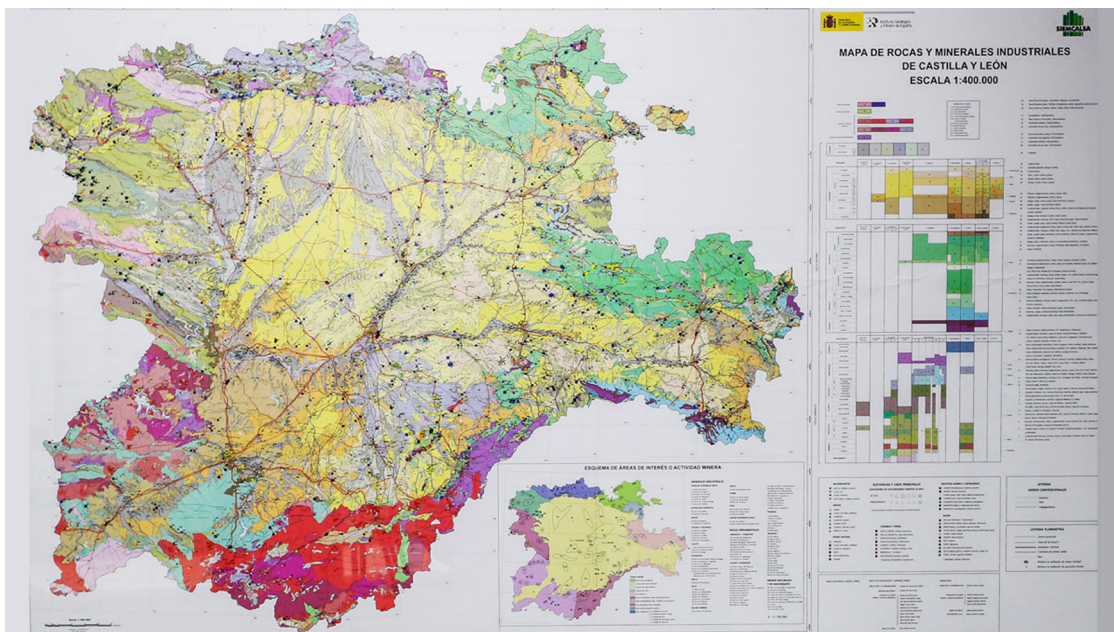
deposit, (active, inactive, etc), the size of it. The substances detected or exploited are indicated by an abbreviation. Each field and operation has an identification number that allows the location of the corresponding data sheet. The cartographic units are differentiated by

patterns of different patterns and colors. The maps also include a 1: 200 000 topographic base.

In March of 2017, a new work from the IGME about Industrial rocks map from the Castilla y León area was presented (fig. 6).



**Fig. 5.** Industrial Rocks Map at a scale of 1: 200 000 (old series) from León Region  
**Rys. 5.** Mapa zasobów przemysłowych w skali 1:200 000 (stara seria) z regionu León



**Fig. 6.** New Industrial Rocks Map at a scale of 1: 400 000 from Castilla y León Region (2017 IGME)  
**Rys. 6.** Mapa zasobów przemysłowych w skali 400 000 z regionu Castilla y León

There are many more very different information maps. Both institutes are in charge of supplying the base information at the beginning of a mining activity (Estruch Serra M. 2002).

The mining activity is regulated by the Mining Law, the General Regulation of Basic Mining Safety Standards and its Complementary Technical Instructions which detail the regulatory plans for the development of the mining project.

#### 4. CARTOGRAPHIC ORGANIZATION ACCORDING TO THE MINING LEGISLATION

One of the most important definitions reflected in the Mining Law (<https://www.boe.es/buscar/act.php?id=BOE-A-1973-1018>) as the principle of the delimitation of the work areas of the mining project is the mining grid, an indivisible unit used to demarcate mining permits and concessions. The law defines it as the volume of indefinite depth whose surface base falls between two parallels and two meridians, whose separation is twenty sexagesimal seconds, which must coincide with whole degrees and minutes and, where appropriate, with a number of seconds that it will necessarily be twenty or forty (<http://www.minetad.gob.es/energia/mineria/Seguridad/Paginas/Legislacion.aspx>).

Permits and concessions are granted over a specific and specific extent measured in mining grids grouped without continuity solution, so that those with a common point are joined along the entire length of at least one of their sides. The perimeters of these extensions must be defined by geographical coordinates, taking as a starting point the intersection of meridian with the parallel that corresponds to any one of the vertices of the perimeter, in such a way that the surface is constituted by one or several mining grids. The lengths are referred to the Greenwich meridian and the latitudes to the equator. As for the geodesic reference system, it has been modified, since the law came into effect in 1973 up to the present time. At the beginning of the application the DATUM ED-50 was used with the reference ellipsoid International 1924 or Hayford and with the fundamental astronomical point Postdam.

Since August 29, 2007 a Royal Decree regulates the adoption in Spain of the European Terrestrial Reference System ETRS89, replacing the local reference geodetic system ED50, official until then in the country and

on which all the official cartography is currently being compiled. the scope of the Iberian Peninsula and the Balearic Islands, and the REGCAN95 system in the Canary Islands (compensation of the geodesic network of the Canary Islands, within the framework of the National Geodetic Network by Spatial Techniques, REGENT completely compatible with the ETRS89 system), allowing a complete integration of the official Spanish cartography with the navigation systems and the cartography of other European countries.

As regards the cartographic projection used in mining cartography, until the year 1970 the conical projection conformed of Lambert was used, that, although the Law of Mines is later still exists mining documentation in this system. From this date the Universal Transverse Mercator (U.T.M.) is adopted as an official projection.

The coordinate representation systems that must be used to compile and publish the cartography and official geographic information are: for terrestrial, basic and derivative cartography, the ETRS89-Transverse Mercator coordinate reference system.

#### 5. REGULATORY PLANS IN MINING

As a development of the Mining Law (<https://www.boe.es/buscar/act.php?id=BOE-A-1973-1018>), in 1985 the Basic Mining Safety Regulations and its Complementary Technical Instructions (ITC) (<http://www.minetad.gob.es/energia/mineria/Seguridad/Paginas/Legislacion.aspx>) were approved, specifying work procedures, rescue measures, preventative training requirements, necessary documents in the projects and details of each of the tasks performed in the development of mining work (Diseño de Explotaciones... 2007).

In this technical development, ITC 04.06.01 (<http://www.minetad.gob.es/energia/mineria/Seguridad/Paginas/Legislacion.aspx>) is in charge of pointing out that in all underground work or exploitation in activity there must be at least the following plans:

- Surface topographic map

In the detailed topographic map (minimum scale 1: 5000) will be important works and buildings, towns, water currents and, in general, as much as it may suffer damage derived from mining or constitute a danger to it. Likewise, the bounded position of each one of the mouths of the wells, tunnels and deposits of explosives will be indicated.

– General plan of mining works

In the general plan of work (1:2000 scale) will be represented the work performed, even abandoned, which will be clearly distinguished, and the work in progress. Among the abandoned ones, the inaccessible ones will be indicated.

If there is a well-founded suspicion of old work not included in the available plans, the operator will take the necessary preventive measures, carrying out, if necessary, reconnaissance work.

– Detailed plan of pits

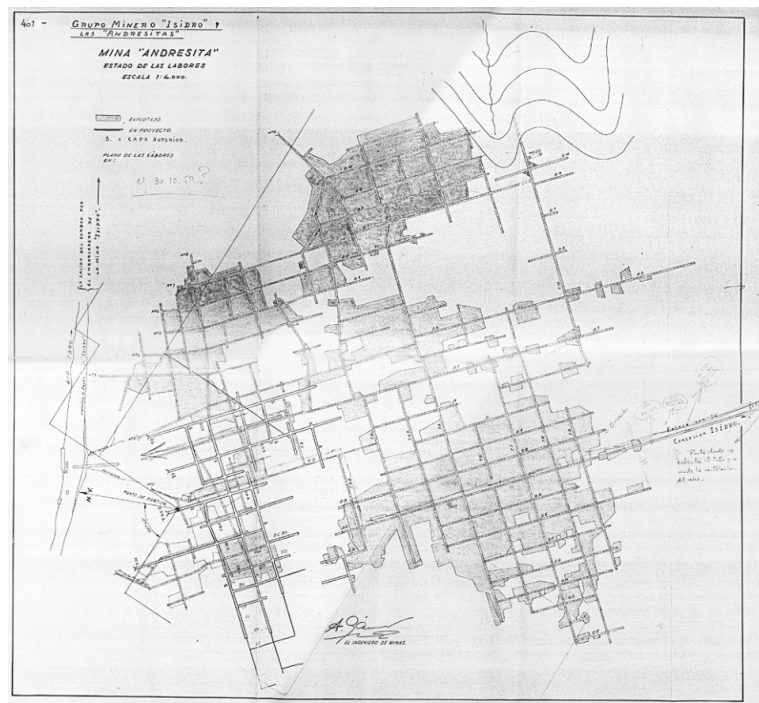
In the detailed plans of pits (depending on the type of exploitation) will include the horizontal or vertical projections, as well as the transversal and longitudinal cuts of the work.

In metallic mines, whenever the structure of the deposit advises it, a metallization chart will be indicated in the vertical projection. To avoid confusion, when on the same plane two or more plants have been projected, each one of them will



**Fig. 7.** Surface topographic map of Figaredo Mining exploitation

**Rys. 7.** Mapa topograficzna z obszaru eksploatacji górnictwa Figaredo



**Fig. 8.** General plan of mining works

**Rys. 8.** Plan ogólny robót górniczych



be represented in a different color, and if there are several breeding sites, their respective vertical projections will be represented separately.

The scale that is generally adopted in the detail plans of work will be 1: 1000.

- General plane of ventilation
 

The ventilation plan (scale 1: 5000) will be made in accordance with what is required in the section related to ventilation and drainage requirements.
- The plan or sketch of the electrical network, to an appropriate scale, will be carried out as indicated in the Complementary Technical Instruction corresponding to the electrical network (Ramos Barbero B., García Maté E. 2016).
- General plane of compressed air.
- General plan of internal communications.
- General plan of the water network, in case there are any.
- General map of transport.
- General exterior map.

Each and every one of these plans, in addition to complying with the rules of development of the mining law, are carried out in compliance with the ISO and / or UNE standards (Spanish standardization body) that are applicable to each subject, as for example the Une 22400: 1974 referring to Working Plans in coal mines (UNE 22400 1974).

## 6. SUMMARY

This paper is a presentation of the cartographic situation in Spain and its application in the field of mining. Two Government Institutes IGN and IGME, created at

the end of the 19th century from then until now they have been responsible for providing maps and data at the service of society. Currently they develop their work based on the INSPIRE directive and the legislation developed from it in Spain.

Likewise, mining cartography is presented through the Mining Law and its development regulations, essential for the proper development of the mining project.

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