ALUMINUM IN SPAIN: MINERAL DEPOSITS AND MINING PRODUCTION

Report prepared by Instituto Geológico y Minero de España for the Metallogenetic Expert Group of ASGMI (Asociación de Servicios de Geología y Minería Iberoamericanos)

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With data from the report by Roberto Martínez Orio and Pedro Delgado Arenas (2020) –IGME

1. **Introduction**

Spain is located in the south of western Europe and north Africa, and it has a continental surface of 505.370 million square kilometers. The peninsular territory shares land borders with France and Andorra to the north, with Portugal to the west and, with the British territory of Gibraltar to the south. It has an average altitude of 650 meters above sea level and it is one of the most mountainous countries in Europe. The highest altitude in the country is found on the Tenerife island, on Teide volcano, with a height above sea level of 3715 m and 7500 m above the ocean floor. It has 4964 km of coastline.

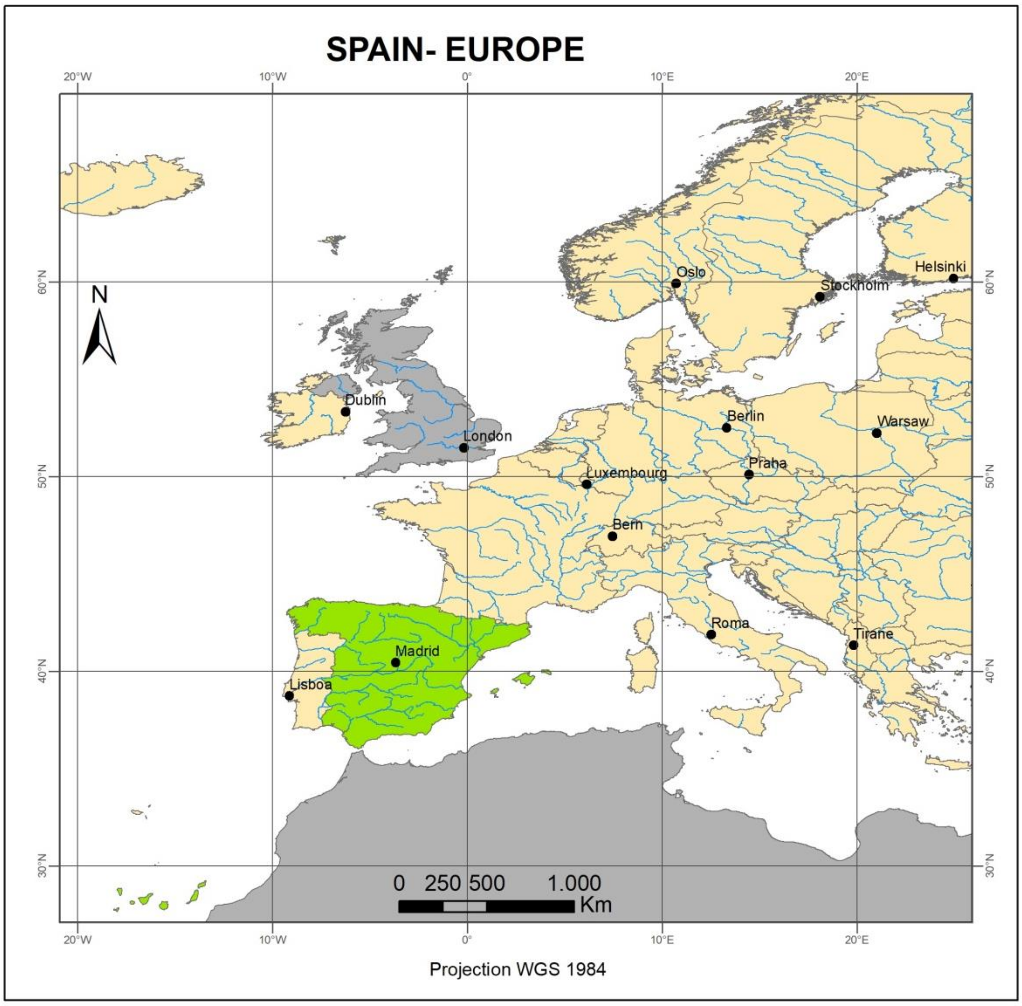

Figure 1- Location of Spain

Spain is not an aluminum-producing country. The country's metallic mining production is mainly related to copper, zinc, tin, nickel, gold, silver, lead and, tungsten.

In 2016, only 6 mines related to metal mining were active (Panorama Minero, 2016), while as of 2021 there are 9 active exploitations.

The most important mines in Spain are located within the Iberian Pyrite Belt (IPB), located in the south of the peninsula, within what is known as the Surportuguese Zone (SPZ, Fig. 2), the southernmost subzone in the Iberian Massif. Most of the massive sulphide mines are concentrated in this area, and for a long time it was considered the largest reserve of metal sulphides in the world. The Iberian Pyrite Belt has dimensions of 250x 20 to 70 km and is a Variscan metallogenetic province, which is home to the highest concentration of massive sulfides in the world. IPB contains over 90 VHMS deposits, estimated before erosion at > 1700 Million tonnes (Mt), with 14.6 Mt Cu, 34.9 Mt Zn, 13.0 Mt Pb, 46,100 t Ag, 880 t Au and many other metals, particularly Sn. Eight of these are giant (≥100 Mt) VHMS deposits, namely Rio Tinto, Tharsis, Aznalcóllar-Los Frailes, Masa Valverde, Sotiel-Migollas and La Zarza (Spain) and Neves Corvo and Aljustrel (Portugal). The VHMS deposits are of the felsic-siliciclastic type and mostly of the Zn – Pb – Cu and Zn – Cu – Pb metal content types (Inverno et al., 2015).

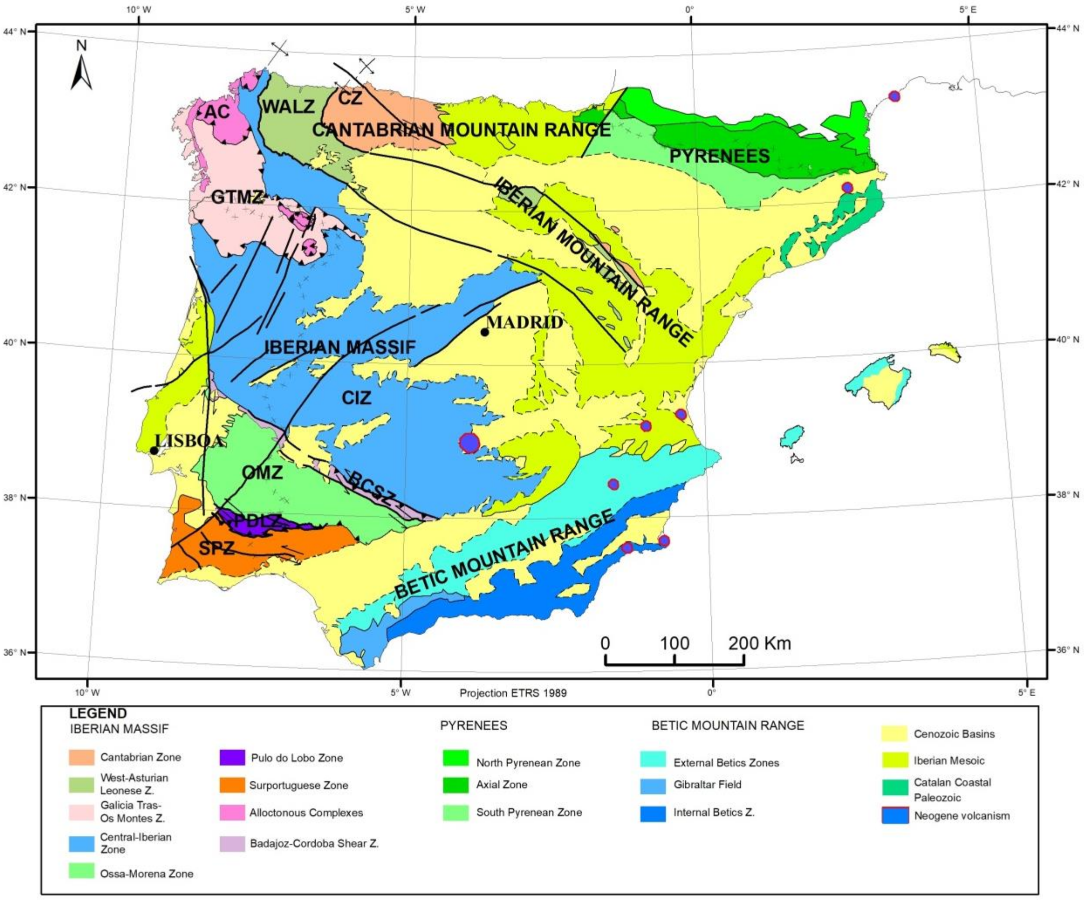

Figure 2- Main geological units of the Iberian Peninsula. Zonal subdivision of the Iberian Massif (modified from Julivert et al., 1974, Quesada, 1991)

Currently, the Aguas Teñidas and Riotinto mines (Huelva province) are active in the ZSP, which mainly extract copper. Also in this area is the Las Cruces mine (Seville province), which is the largest open-pit mine in Europe and one of the most important in the world.

The Barruecopardo and Los Santos mines exploit tungsten and are located in the province of Salamanca, NW of Spain, Central Iberian Zone (CIZ) (Fig.2). The Barruecopardo mine has a large mining tradition that spans the entire 20th century. Mining operations are known to exist since 1902. It is a filonian and intragranitic deposit of scheelite. The Los Santos Mine benefits a Skarn-type deposit with Scheelite ($CaWO_4$) mineralization produced by the intrusion of a granite body in carbonate sedimentary rocks and from which a tungsten concentrate is obtained.

In northern Spain, in the Rio Narcea gold belt, in the Autonomous Region of Asturias, the El Valle mine is active. It is in the Cantabrian Zone (CZ) (Fig.2). In this mine, copper and gold are extracted and it has been in operation since 2010.

The main tin mine in Spain, currently open, is the Penouta mine, in the province of Ourense (Galicia Autonomous Region), which also benefits tantalum and niobium. It is located in the Central Iberian Zone (CIZ) (Fig.2). It has had several periods of exploitation during the years 1970-80 of the last century.

Regarding the exploitation of industrial rocks, the Bagés mines, in the Autonomous Region of Catalonia, extract salt and potash. There are two mines, located in the Bages area (Barcelona), one in the municipality of Súria (Cabanasses mine) and the other in the municipality of Balsareny (Vilafruns mine). Potash and salt are exploited.

In the Autonomous Region of Navarra, in northern Spain, the Muga mine is also active, which benefits potash, in the form of sylvinite.

2. Geological setting

Despite the small size of the Iberian Peninsula, its geology is complex and varied. The geological record includes materials ranging from the Precambrian (600 Ma) to Quaternary materials.

On surface materials, three large geological domains can be seen (Fig. 3): i) the first of them, would be the large tertiary and quaternary basins (in yellow color on the map in figure 3), ii) the other large domain would be the western part of the peninsula, which includes the Precambrian and Paleozoic materials known as the Iberian Massif, which is part of the European Variscan Orogen (different zones on figure 3), and iii) the eastern and southern half of the peninsula and the Balearic islands, that are part of the belt westernmost extent of the Alpine–Carpathian–Himalayan orogenic system, and that are mainly made up of Mesozoic rocks (green and dark purple colored in figure 3), although some Precambrian and Paleozoic basement inliers also exist. (Quesada & Oliveira, 2019).

We must also mention the quaternary volcanism, present in the Canary Islands, and in small outcrops of the Iberian Peninsula.

According to Quesada & Oliveira (2019) from a geodynamic point of view, several events are recorded in Iberia, the most significant of which relate to the following global scale processes:

- Amalgamation of Gondwana in the Neoproterozoic (Cadomian arc and orogeny),
- Cambrian rifting that led to opening the Rheic Ocean in the Lower Ordovician,
- Drift of Gondwana from Lower Ordovician to Devonian times,
- Subduction and collision with the Laurussian plate to form Pangea (Variscan orogeny) in the Lower Devonian–Lower Permian interval,
- Various rifting events that led to Pangea’s breakup by sequential opening of the Neotethys, North Atlantic and Biscay oceans (Upper Permian–Lower Cretaceous)

• Individualization and drift of an Iberian microplate during most of the Cretaceous,

• Collision with the Eurasian plate in the north and with the African plate in the south (Alpine orogeny) from the latest Cretaceous to the present.

All these events marked a footprint in the deformation, magmatism and, metamorphism history, in all lithospheric levels, as well as in the formation of basins and their subsequent evolution. Likewise, all these events have conditioned the formation of different mineral deposits.

3. Mineral deposits of aluminium

Aluminum mineral deposits in Spain are scarce and small. In the IGME database of mining prospects (BDMIN), there are only 29 registered occurrences and deposits that are reflected in the map of figure 3. The most significant results of geological studies and research surveys are listed below, developed in a number of favorable areas of the Spanish geography selected by the IGME to determine the aluminous ore resources in Spain (IGME 1982).

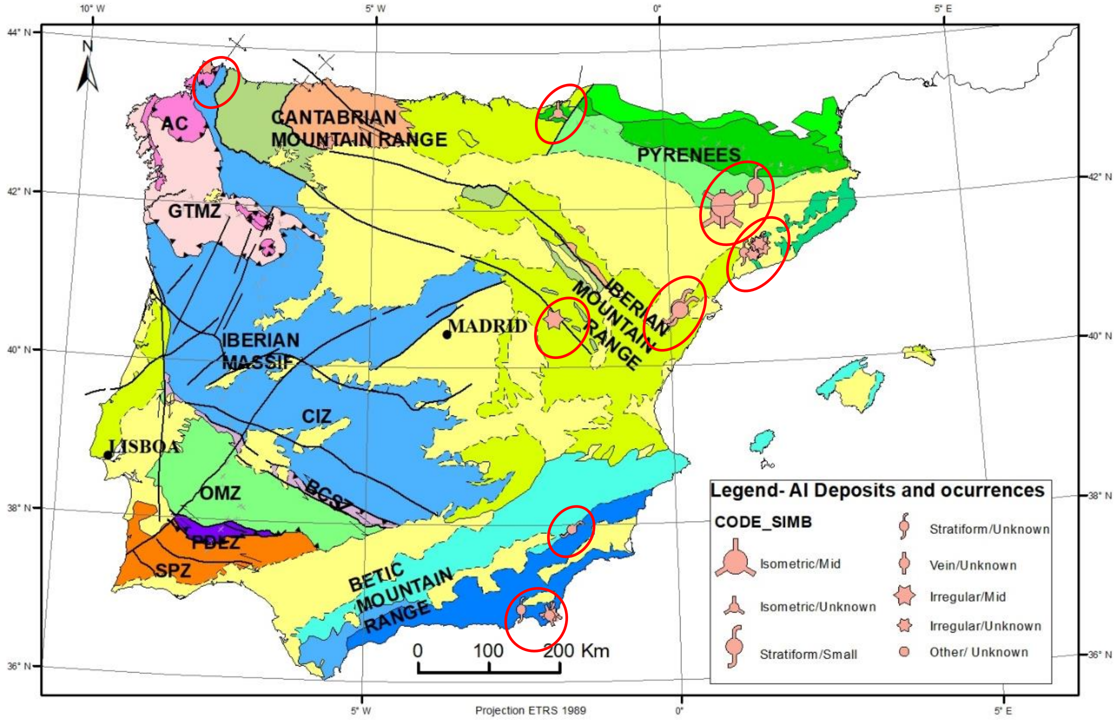

Figure 3. Main ocurrences and deposits of aluminum in Spain

Mid 70's an exploration project of aluminous ores was carried out in the Northwest Reserve of Spain, studying mainly andalusite. The study comprised three different phases of research, and the result was that the andalusites of the NW of Spain are not even a subeconomic resource.

Different sectoral programs have also been carried out in different areas, which are detailed below.

Aluminum minerals sector program, NE of Spain, La Llacuna Area (Barcelona-Tarragona)

Discontinuous and widely dispersed deposits of bauxite mineralizations. They were exploited in the provinces of Barcelona and Tarragona. Only the outcrops of the Plana de Casals area stand out, although the volume estimates are scarce and uninteresting.

Aluminum minerals sector program, NE of Spain, Fuentespalda Area

This area is located between the provinces of Tarragona, Teruel and Castellón, in the massif of Puertos de Beceite or Tortosa, with an area of 78000 Ha.

In it, different groups of bauxites have been differentiated, on siliceous rocks or carbonates, distinguishing:

- Pisolytic bauxites (type 1), with SiO_2 between 7.1-43.6%, Al_2O_3 between 9.3 and 46.8%. These silica contents, together with their low volume, mean that they are considered without exploitation interest.
- Bauxitic lateritic clays (types 2 and 3): with an average composition of SiO_2 of 36.9% and of Al_2O_3 34.9%, and Fe_2O_3 of 12.6%. They present resources of 80 MT of type 2 and 22 MT of type 3.
- -Bauxitic lateritic clays (type 4). $Si0_2$ 59%, Al_20_3 59%, Fe_20_3 6%. They total 3 million tons.

Lateritic clays types 2 and 3 constitute approximately 102 million tons of resources, currently subeconomic, as long as alternative processes to Bayer are not developed industrially, for treating aluminum ores with high silica content and the technique viability is confirmed for its use as aluminum ore.

Aluminum minerals sector program, Central Subsector, Villacorta-Riaza Area

The surface of the studied area is about 500 km2 and covers part of the province of Segovia and part of those of Soria and Guadalajara. The ore detected are alunite, together with iron oxides. The area with the greatest enrichment and the greatest quantity of mineral ore is precisely the one where old exploitations (Negredo and Madriguera open pits) were located.

However, the low thickness of the ore sections and the irregularity of their spatial distribution, as well as the abundance of fractures of the Paleozoic bedrock, do not support optimistic expectations. The grades, on the other hand, are quite discreet, since the percentage of Al_20_3 does not normally exceed 30%, while, in turn, silica is usually greater than 45%.

Due to its characteristics, it is not considered an interesting resource.

Aluminum minerals sector program, NW Subsector, Valle del Oro Area (Lugo)

In this area, sillimanites have been studied as the main aluminum resource. Estimates have been made at 4 million tons of mineral with an Al_20_3 content close to 30%. The analyzed samples present 36% silimanite in their mineralogical composition. Its chemical composition is as follows: $Al_2$03 28.2-32.7%, Si02 58.4-62.8%, Fe_20_3 range between 3.8-5.1%. Some assays were carried out with this material by different industrial firms, achieving through flotation and magnetic separation, a concentrate whose composition is of particular interest: Al2O3 58.6-60.7%, SiO2 35.9-37.8%, Fe2O3 0.8-1.1%.

In the absence of a more in-depth research survey, the 4 million tons of "run of mine " that have been registered can be considered as subeconomic resources in this deposit.

Like Andalusite, sillimanite is only exploited for later use as a raw material in the production of refractory materials with a high alumina content. This is the experience of South Africa at an industrial level, where a material more enriched in Al_20_3 than that of the Gold Valley and with a lower silica content benefits. Therefore, no perspective is contemplated to consider the concentration of sillimanites, referred to as a resource from the point of view of aluminum metal.

The main conclusion of this study is that “it is possible to verify the absence of authentic aluminum ore resources registered in Spain to date. The aluminum ore deposits identified cannot, from any point of view, be exploited for the production of alumina due to the high content of silica, although with certain limitations, their product serves as a raw material for the chemical industry of abrasives, refractories and cements ”.

4. Conclusions and resources in Spain

Aluminum is a very abundant metal in the earth's crust and requires significant concentrations and volumes to consider its industrial production viable. Previous knowledge about this mineral does not invite optimism regarding its mining potential, having estimated slightly more than 100 million tons of resources that, at the time, were subeconomic, in the Teruel-Tarragona area, which would a priori be the only one in which it would be interesting to develop a further study..

According to Martinez Orio and Delgado (2020), the fundamental repository of information is the Documentation Center of the Geological Survey of Spain itself, which harbor the bulk of the reports that, on research on mineral resources and reserves, have been made systematically in Spain since the second half of the 20th century. To assess reserves, only those reports from mining companies based on internationally accepted reference codes have been taken into accounts, such as the Canadian NI-43-101 or the Australian JORC. The rest of the figures have been shown, generically, as resources, since there is no reliable assessment as to whether they are indicated resources, inferred or, hypothetical resources.

5. References

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