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Geothermal Resources in Spain (Basin, Volcanics and EGS)

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ABSTRACT

This paper will evaluate the current state of the art for the definition ofgeothermal resources in different geothermal environments and applications in Spain, showing the current findings and the forthcoming challenges.

Spanish geothermal potential began to be investigated in the 1970's by the Geological Survey of Spain (IGME) within the framework of the PEN (National Energy Plan) that tried to define alternative and local solutions to the 1970's world energy crisis that was specially affecting to the Spanish economy due to the energy dependency from external sources.

As a result of the preliminary studies undertaken by IGME including basic geology, geochemistry, geophysics and in some cases geothermal wells, several areas with relevant geothermal anomalies in both, island and mainland environment were defined.

1. Introduction

Geothermal energy is reviving after several decades of low development in Spain. Since the late 1980's to mid 2000's there was no geothermal investigation and development. However interest from this sector has just recently restarted. Exploration Companies, Technological Institutes, Universities, regional and federal governments are becoming active in the last year and are starting to coordinate joint initiatives to promote the development of the geothermal energy in Spain. The main efforts are being driven at the moment to obtain a detailed definition of the geothermal resources, the validation of the technical and economic parameters that will make the geothermal resources viable, and the development of an appropriate legal and administrative framework for the development of the industry.

At least 50% of the country has very little deep geothermal information or remains almost unexplored (see Figure 1). New regional exploration programmes coordinated by the government, and with the input of the industry, are needed in order to increase the geothermal potential of the country and to provide new data to the companies to stimulate new detailed geothermal investigation.

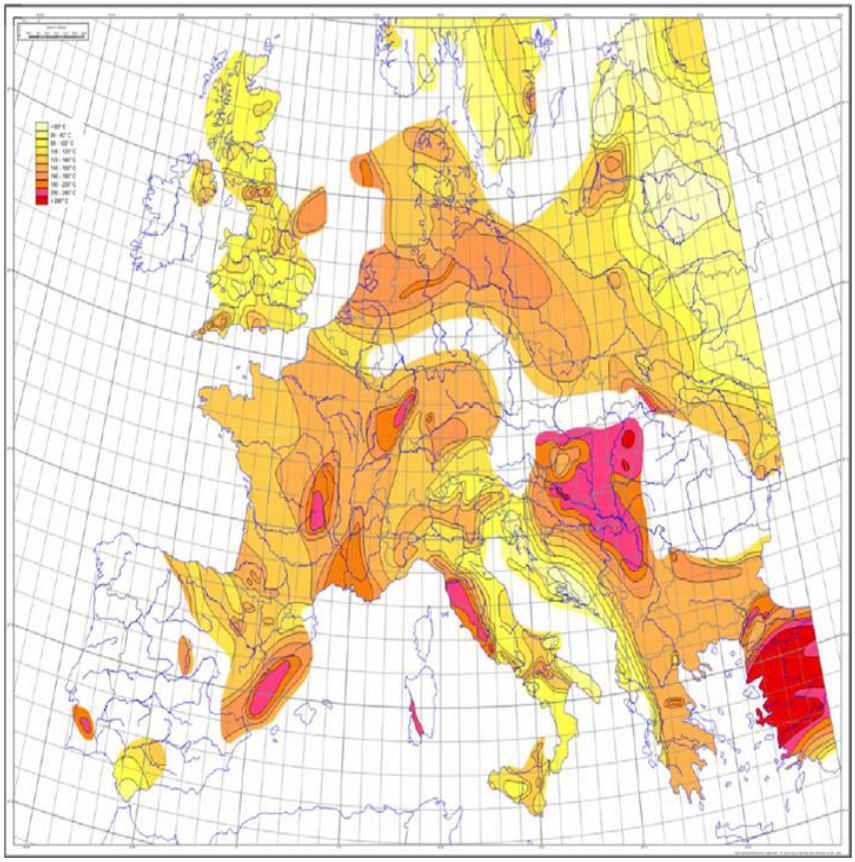

Figure 1. Modified fron Geothermal Atlas of Europe (Fernandez et Al 2002).

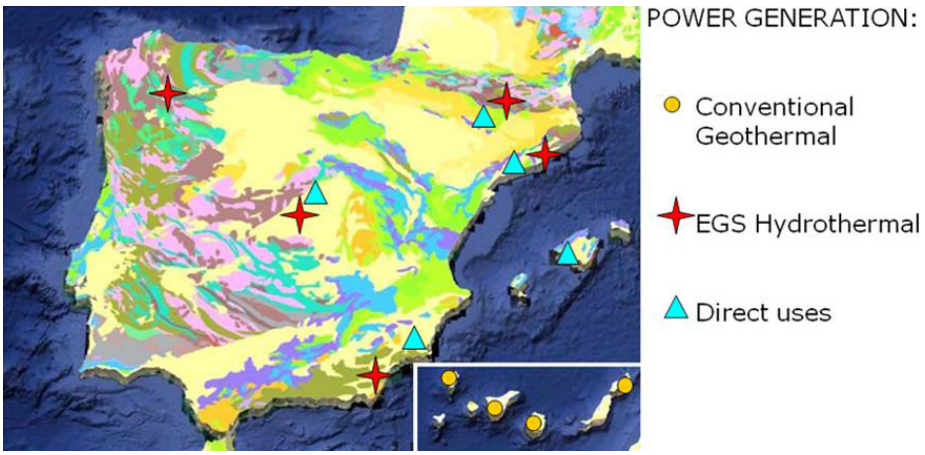

Figure 2. Location of the different potential geothermal areas in Spain.

In the last two years several private company initiatives have begun to apply for exploration and investigation licenses covering areas with higher volumes of data. In these areas historical data has allowed the companies to do a quick data validation process from which detailed investigation programmes have been developed.

Some of the key areas which companies are working in include the Canary Islands, with potential to develop a conventional geothermal system, mainland Cenozoic undeformed basins and deep fault systems suitable to host convective and enhanced geothermal systems. (Figure 2)

2. Canary Islands

The Canary Islands constitute the only active volcanic area in Spain and include geothermal surface manifestations like Teide volcano fumaroles on the island of Tenerife, where the gas analyses at the summit are consistent with steam derived from a mature liquid dominated geothermal reservoir with temperatures in the range of 250 to 300ºC (HERNANDEZ ET AL 2000) (Figure 3). The Geological Survey of Spain (IGME) undertook an important campaign of exploration in collaboration with other institutions from late 1970's to mid 1990's. Their work was mainly focus in the ground water temperature and geochemistry but also some magneto-telluric (MT) campaigns were undertaken between 1977 and 1990 on Tenerife Island (IGME 1987, ITGE 1993).

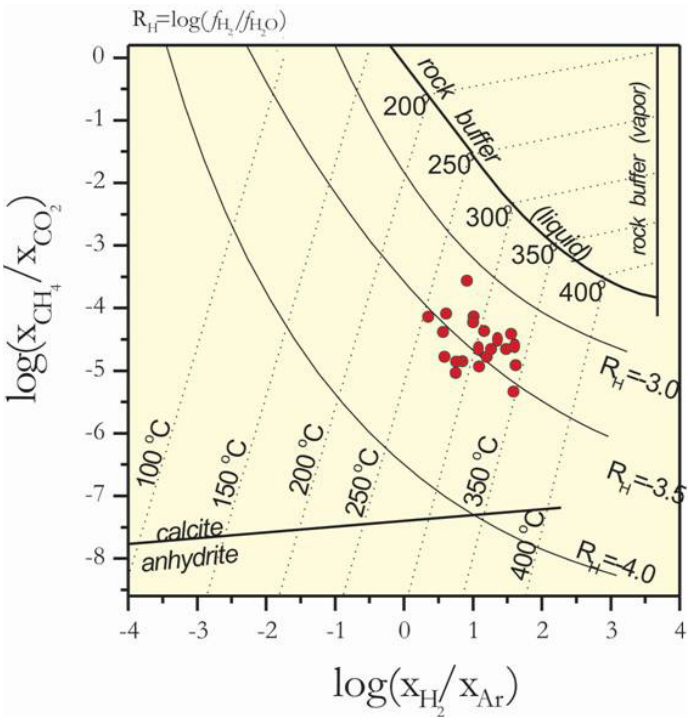

Figure 3. CH_4/CO_2-H_2/Ar Geothermometer calculated from Teide summit fumarole (Hernandez et al 2000).

During 2007-2008 Petratherm España s.l. was developing in conjunction with the Technological Institute of Renewable Energies (ITER) a full compilation of all existing geochemical, geological and geophysical data from Tenerife and Gran Canaria Islands. The main conclusion of this compilation study is the confirmation of a presence of a deep liquid reservoir supported by isotope data like ^{18}O, ^{2}H, ^{3}He, ^{13}C, ^{34}S, ^{18}O exchange SO4 – H2O and a large, widespread CO_2 flux.

Although the existence of hydrothermal systems in the Canary Islands, especially in Tenerife, is confirmed, the meteoric foot print of the ground water and the existing MT data suggests that these systems lie deep within the volcanic massif and seem to be largely hydrologically isolated from the surface by the thick pile of volcanic rock and cold groundwater.

As a conclusion, the Canary Islands hydrothermal systems will only be mapped using very deep penetrating geophysical methods like MT and that will form part of the next stage exploration strategy to be develop in the islands in order to define the drilling targets.

3. Mainland Tertiary Basins

Almost 50% of Spain is covered by undeformed Cenozoic basins associated in many cases with rich U, Th and K granitic rocks (ITGE 1991). The combination of low thermal conductive thick sediment cover with thermally active granite provides a good geological setting to produce sedimentary geothermal and enhanced geothermal systems.

The Iberian Peninsula hosts several important Tertiary basins, Guadalquivir, Tajo, Duero, Ebro with associated geothermal manifestations along the basin boundaries. In the Madrid and Pyrenees Basins, temperatures above 150 degrees have being measured from historical oil wells at depths from 3500 to 4000 m. Additionally most basins have associated hot aquifers that could be exploited for direct thermal uses in industrial processes and district heating grids, this such recorded in the Burgos (Duero Basin) and Madrid (Tajo Basin) areas respectively (ITGE 1990).

Detail basin structural reconstruction is being conducted in several zones utilising the drilling information together with the seismic profiles, gravity and MT data. This existing data is being used to build 3D geological models that allow defining of deep geothermal drilling targets.

4. Enhanced Geothermal Systems

EGS systems in Spain are associated with Thermally Active Granites. Several heat anomalies and surface manifestations like hot springs with temperatures higher than 75-80 ºC occur in conjunction with structural features like major faults in areas like Galicia and Catalonia (FERNANDEZ ET AL 1990). Deeper portions of these convective systems, below 3000 m may be suitable for the development of mid enthalpy (above 150ºC) enhanced geothermal systems. In low permeability areas stimulation of the pre-existing fracture systems within the granites may be required to develop a fluid circulation cell.

New regional exploration and investigation within these areas will be focussed on a better definition and correlation studies about heat flow and thermal conductivity associated to different granitic units, in order to discriminate thermal active from barren granites.

Table 1. Classification of types of geothermal energy in Spain. Modified from Garcia de la Noceda et al 2005.

Conventional Geotermal Volcanic Systems		Canary Islands
Hidrothermal Sedimentary Systems	**Main Cenozoic Basins**	Tajo Basin: Madrid Duero Basin: León, Burgos and Valladolid Guadalquivir Basin
	Small-Medium Basins	Catalonian Ranges: Vallés, Penedés, La Selva y Ampurdán Betic Range Internal Basins: Granada, Guadix, Baza, Pirinees Internal Basins:Jaca-Sabiñánigo
Enhanced Geothermal Systems		Associated to the crystalline granitic basement of the above described basins Hercinian thermal active granites associated to deep fault convective systems: Galicia.

5. Conclusions

Spain presents several favourable environments with potential to hold volcanic convective hydrothermal, conductive sedimentary and enhanced geothermal systems suitable to generate electricity. There are also a lot of low temperature resources close to noticeable heat demand areas like Madrid and Barcelona cities, which makes them very favourable for the direct heat uses and the development of Geothermal district heating grids.

The progress of the geothermal energy in Spain will require further exploration drilling and the development of new investigation and exploration techniques to discover the geothermal potential in areas with very low volume of information. This will require a combined effort of both federal and regional governments and private companies.

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