Deep Geothermal Energy Potential in the Madrid Basin

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ABSTRACT

The Madrid Basin geothermal potential was discovered in 1980 thanks to an oil exploration well drilled by Shell-Campsa which showed temperatures of 88ºC and 156ºC degrees at 1700 mts and 3400 mts depth respectively. That low enthalpy geothermal reservoir was further assessed by four exploratory wells. The latest well was drilled in 1990.

These wells have identified a dependable geothermal resource, hosted in a Tertiary, clastic, consolidated sandstone reservoir consisting of a thick multilayered sequence (200-800m) with temperatures ranging from 70º to 90ºC and depths of 1500 to 2150 m., overlying a Mesozoic sequence, suitable to be exploited for thermal uses in several district heating grids around Madrid in areas displaying adequate heat loads.

A medium-enthalpy reservoir was also identified at the contact between Mesozoic Cretaceous limestones and fractured basement granites at 3400m depth, with measured temperatures of 156ºC, that could be developed and exploited using a combined power and heat production (CPH) scheme within the Madrid suburban areas.

Introduction

The low enthalpy geothermal reservoir was assessed thanks to four exploratory wells drilled in the 1980s at the Pradillo (original's Shell oil well), San Sebastian de los Reyes, Tres Cantos and Geomadrid 1 locations. They enabled to identify a dependable geothermal resource, hosted in a Tertiary, clastic, consolidated sandstone reservoir consisting of a thick multilayered sequence (200-800m) with temperatures ranging from 70º to 90ºC, overlying a Mesozoic sequence. The reservoir is located under the city of Madrid and surrounding localities.

The Madrid northern suburban areas enjoy one of the most favourable geothermal environments identified to date in Metropolitan Spain. The four exploratory wells drilled in the area (see locations in Figure 1 map) namely:

- El Pradillo 1 (Shell, 1980) 3400 m
- Tres Cantos (IGME, 1981) 2400 m
- San Sebastian de los Reyes (ENADIMSA, 1982) 2100 m
- Geomadrid 1 (ENADIMSA, 1990) 2000 m,

alongside geophysical investigations (mainly seismic lines) and well tests, led to the local geothermal potential, portrayed in Figure 1which maps the features of the Tertiary clastic deposits set as a priority development target, given (i) its higher than normal subsurface temperatures (75 – 90 °C at ca 1800 to 2400 m depths), and (ii) its dependable reservoir properties (# 100 m net thickness, 20 to 45 dm transmissivities) eligible to 200 – 250 m^3/h well productive capacities.

Geology

The Madrid Basin constitutes the central sector of the Tajo Basin one of the largest Tertiary undeformed basins of the Iberian Peninsula. It shows a triangular shape bounded to the north by the Sierra de Guadarrama, to the south by the Toledo Mountains and to the east by the N-S trending Altomira range (Figure 2).

It exhibits a wedge shape morphology; thicknesses are maximum to the north where sediments reach 4,000m and are bounded by the crystalline basement rocks, mainly granites and gneisses. Sediments are thrust by basement rocks to the north, delineated by the North Madrid Sierras (Central System Mountain Range). Those thrust structures are evidenced by deep parallel faults trending SSW-NNE (SANCHEZ GUZMAN 2007) (Figure 1)

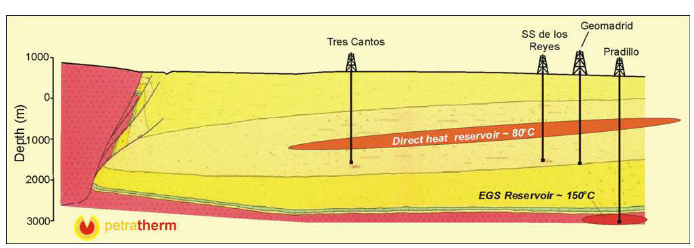


Figure 1. Madrid Basin N-S section, modified from IGME showing the position of the geothermal wells.

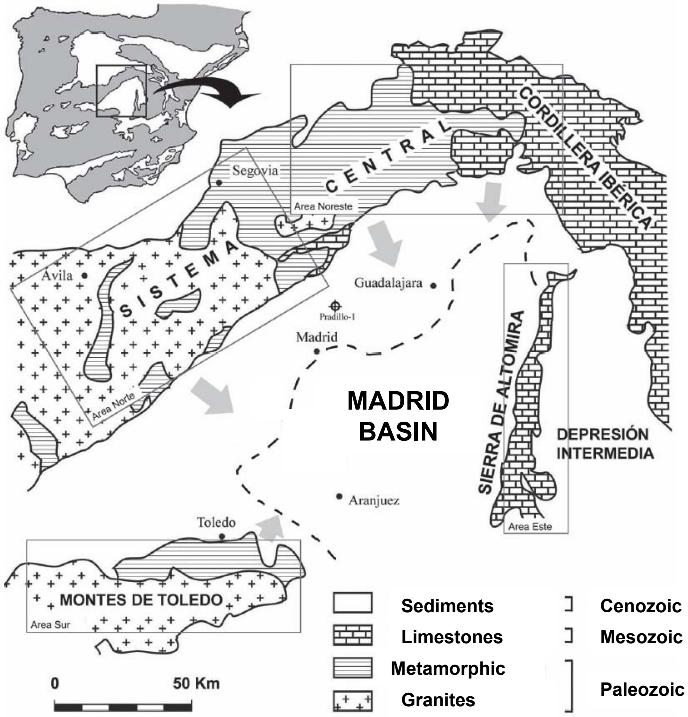


Figure 2. Madrid Basin structure modified from Calvo et al (1989).

Basin Stratigraphy

The Madrid basin is bounded by a Variscan crystalline basement (granites, shales, schists and gneises) filled with fluvial and lacustrine Mesozoic and Cenozoic deposits.

Cretaceous.- with a variable thickness between 100 to 250m, it is formed by sandstones limestones and mudstones , laid unconformable on top of the Paleozoic basement.

Paleogene.- Composed of lagoon deposits, marls and limenstones with thicknesses of about 200mts.

Upper Paleogene-Neogene.- it constitutes the major portion of the northerm part of the basin and comprises two major units (i) the lower detritic unit formed by agglomerates and sandstones moving laterally to the south to sandstones and mudstones, (ii) and the upper detritic zone located in the northernmost area , formed by agglomerates and sandstones.

These continental sediment facies are varying significantly within the basin from north to south; the northern side is mainly detritic, while the southern part is evaporite-lacustrine dominated.

Low Enthalpy Geothermal Potential of the Tertiary Detritic Units

Pradillo oil well (SHELL-CAMPSA, 1980) identified a main hot aquifer unit consisting of a thick multilayered sequence of Tertiary detritic, consolidated, sandstones overlying the cretaceous unit (ADARO 1981).

The geothermal discovery in the Pradillo well stimulated new research programmes in the mid 1980's to evaluate this potential within different areas of the basin. As a result three new geothermal wells were drilled, Tres Cantos, San Sebastian de los Reyes and Geomadrid 1, covering an area of ca 150 km^2 and demonstrating the continuity of the reservoir down deep over the whole area.

These geothermal wells provided valuable information regarding formation temperature, reservoir structure, permeability and water quality further to logging and bottomhole testing and sampling.

Apart from drilling data, the seismic lines carried out by Shell in the 1970's, initially aimed at investigating the potential of the Cretaceous gas-oil reservoir confirmed the continuity of the hot Tertiary clastic aquifer from the northern basin boundary at least to the south of Madrid City (ENADIMSA 1983)(see Figure 3).

The highlights of the low enthalpy reservoir are summarised in Table 1.

Table 1. Madrid Geothermal well summary sheet.

Well	Tested Intervals (Depth)	Transmissivity	Temperature ºC	Salinity	Estimated flow
Pradillo	At 1600-1800 m	46.6 dm	70º-80º	20-30 g/l	150 m^3/h
Pradillo	At 3400 m		150º		
Tres Cantos	1600-2400 m	20.3 dm	70º-90º	12-90 g/l	150 m^3/h
San Sebastian de los Reyes	1600-2100 m	35.3 dm	75º-90º	12-30 g/l	250 m^3/h
Geomadrid 1	1550- 2000 m	44.4 dm	70º-78º	20-25 g/l	200 m^3/h

Geomadrid District Heating Projects

As a result of these promising resource Characteristics matching a significant energy demand in such densely populated areas, Petratherm España applied for geothermal mining rights on the area.

A thorough prefeasibility study was further undertaken in early 2008 in order to evaluate the geothermal resource, existing well deliverabilities and the heat demand structure within the vicinities of the existing wells.

The prefeasibility analysis led to select the Cantoblanco/Valdelatas district nearby the Geomadrid1 well (see locations in

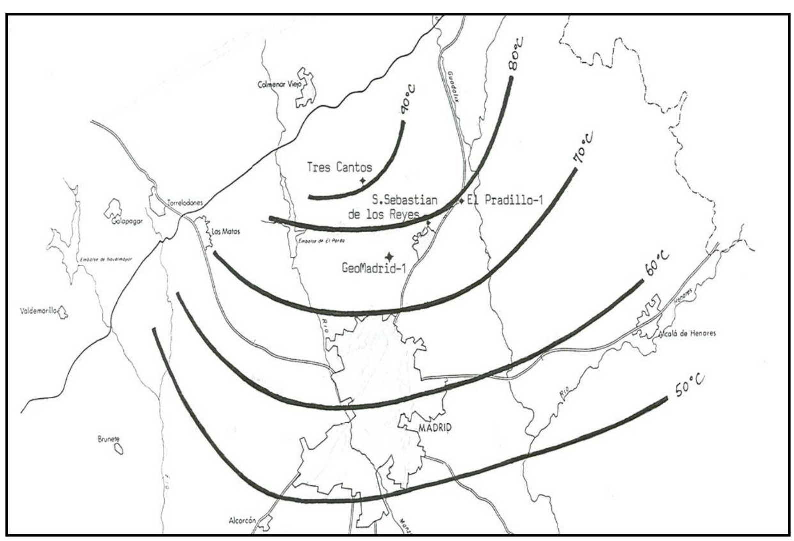
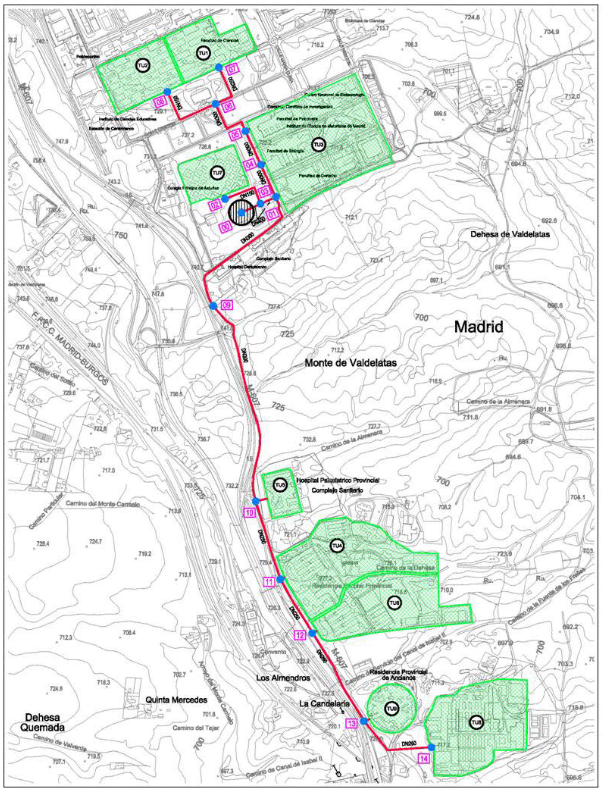


Figure 3. Tertiary clastic, low enthalpy reservoir isotherms.



LEGEND	
DNxxx	CENTER LINE OF DISTRICT HEATING NETWORK (DELIVERY + RETURN) WITH NOMINAL DIAMETER (XXX = MILLIMETER)
mn	DISTRICT HEATING NETWORK JUNCTION POINT, WITH ITEM
TU	THERMAL USER AREA AND ITEM
TU1	UNIVERSIDAD AUTONOMA MADRID (1)
TU2	UNIVERSIDAD AUTONOMA MADRID (2)
TU3	UNIVERSIDAD AUTONOMA MADRID (3)
TU4	SAN FERNANDO
TU5	HOSPITAL PSIQUIATRICO
TU6	ACADEMIA DE POLICIA LOCAL DE MADRID
TU7	NUESTRA SENORA DEL CARMEN
TU8	CENTRO ESCOLAR
TU9	RESIDENCIA DOCTOR GONZALES BUENO

Figure 4. Planned Cantoblanco/Valdelatas district heating grid.

Figure 4), which exhibits a 8 to 10 MWt installed capacity, as the best candidate and to commission a detailed feasibility survey aimed at assessing whether the local resource to heat, cold and sanitary hot water demand adequacy would be met at technically feasible, economically viable and environmentally safe conditions, given the important heat & cold (H & C) / sanitary hot water (SHW) load (institutional, educational, medical and old people residence buildings) existing nearby the Geomadrid 1 well.

Simultaneously to the foregoing, a log inspection of well Geomadrid1 (UNGEMACH et AL 2008) carried out, using CIC (casing inspection calliper), CBL/VDL (cement bond variable density logs) and CCL (casing collar locator) tools, in late July 2008, concluded to well integrity. Actually, casing, cementing and slotted liner sections shaped well. . Therefore, it was assumed it could be recovered as an injector unit serving the needs of a future geothermal district heating and cooling (GDHC) doublet scheme according to the load distribution grid sketched in Figure 4.

Conclusions

Summing up, it could be stated that the Madrid basin hosts a dependable geothermal resource capable of contributing (i) to a significant share of heat-cold and sanitary hot water market an area exhibiting fast growing urbanisation trends, and (ii) to the power demand of a city depending in more than 90% from external regional energy sources, by fostering Enhanced Geothermal Systems (EGS) at the basement-Tertiary rock interface displaying higher than 150°C source temperatures.

References

Adaro (1981) "Estudio Geotérmico Cuenca de Madrid, Sondeo Pradillo 1" Estudio para el Plan Energético Nacional.

Calvo, J.P., Ordóñez, S., García del Cura, M.A., Hoyos, M., Alonso-Zarza, A.M., Sanz, E. & Rodríguez Aranda, J. P. 1989. Sedimentología de los complejos lacustres miocenos de la Cuenca de Madrid. *Acta geológica Hispánica*, 243(4): 281-298.

Enadimsa. (1983) "Evaluación de Recursos Geotérmicos en la Cuenca de Madrid " Estudio para El plan energético Nacional."

Sanchez Guzmán J. (2007) "Síntesis de datos Geotérmicos del Yacimiento Detrítico-Terciario de la Cuenca de Madrid", informe interno realizado para Petratherm España s.l. (Unpublished).

Ungemach, P., and Antics, M. (2008). Petratherm España Nord Madrid Basin Cantoblanco/Valdelatas geothermal area assessment of Geomadrid 1&2 well status; log inspection report (Unpublished).