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Presentation given to the recent Geothermal Resources Council 2009 Annual Conference in Reno, Nevada

Please find attached a copy of a recent presentation (and associated abstract) that was delivered by Raul Hidalgo (Petratherm's Spanish Manager), Pierre Ungemach (Chairman – GPC Instrumentation) and José Sánchez Guzmán (TRT) to the recent Geothermal Resources Council 2009 Conference held in Reno, Nevada.

The presentation focussed on deep geothermal energy potential in the Madrid Basin.

Refer attached presentation.

14 October 2009

Yours faithfully

Terry Kallis
Managing Director

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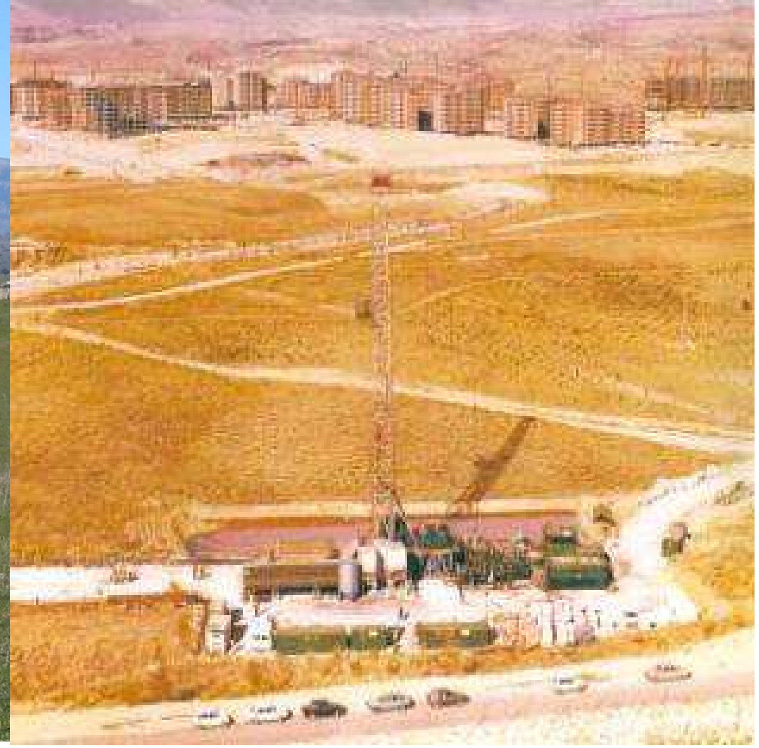


Deep Geothermal Energy potential in Madrid Basin

petratherm Raúl Hidalgo

GPC IP Pierre Ungemach

Tecnología y Recursos de la Tierra, S.A. José Sánchez Guzmán

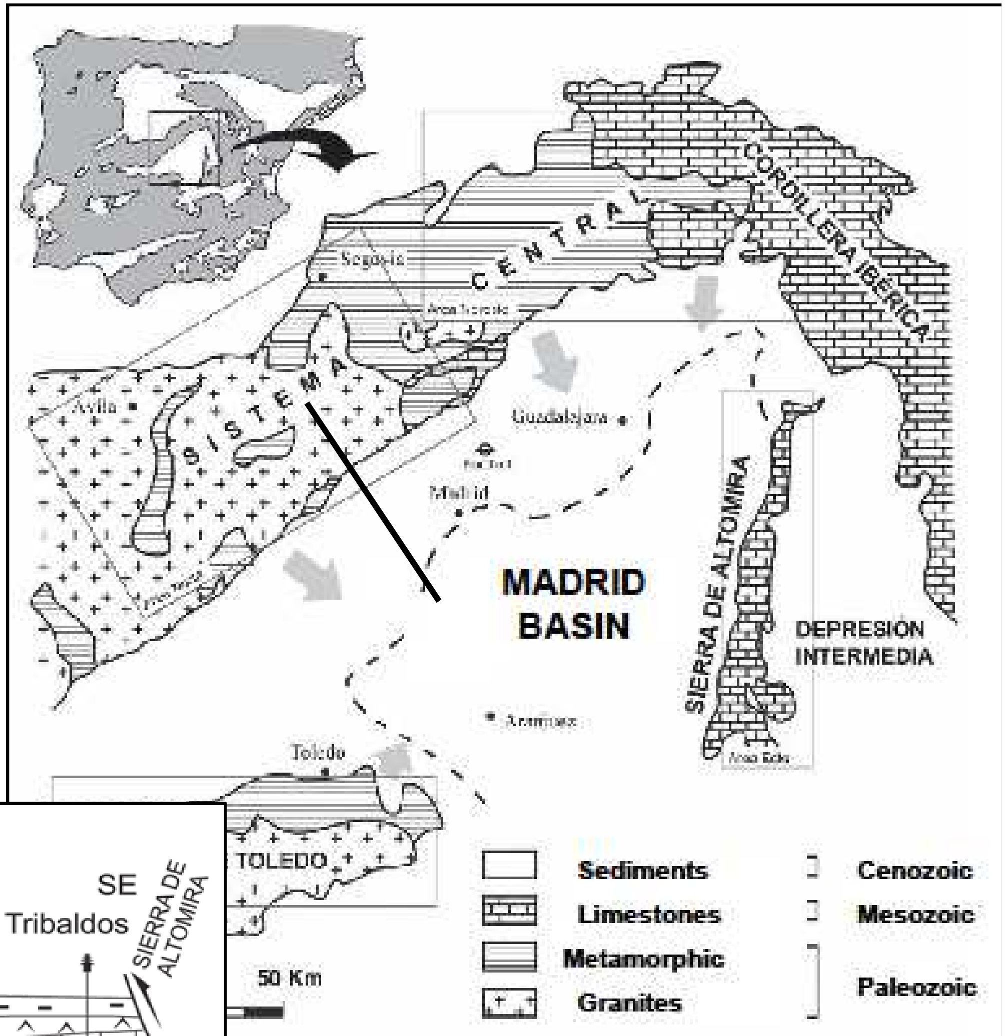
Reno GRC October 2009

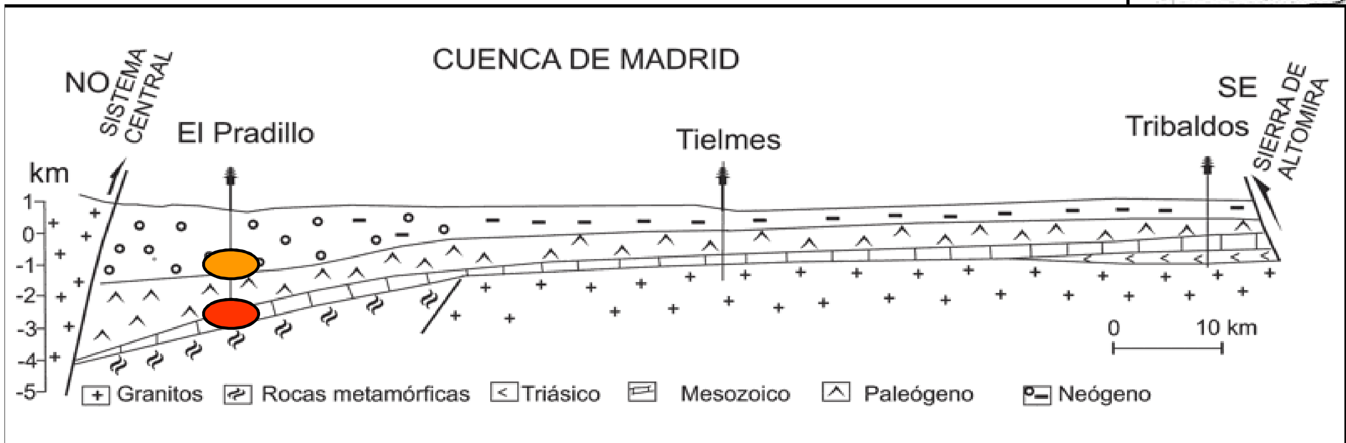
Geological setting and potential

An oil well drilled by Shell 1980 intersected two zones with anomalous temperatures showing the geothermal potential of the basin.

- A low temperature zone, 88ºC at 1.750 m associated to tertiary sandstones.

- A medium temperature zone, 150ºC at 3.400 m associated to cretaceous sediments and to basement rocks contact.

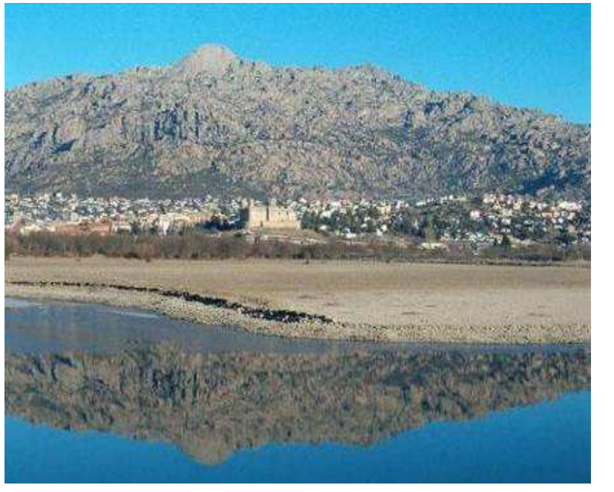




¿Where's the heat source at Madrid?

Central System (CS) has thermally anomalous granites

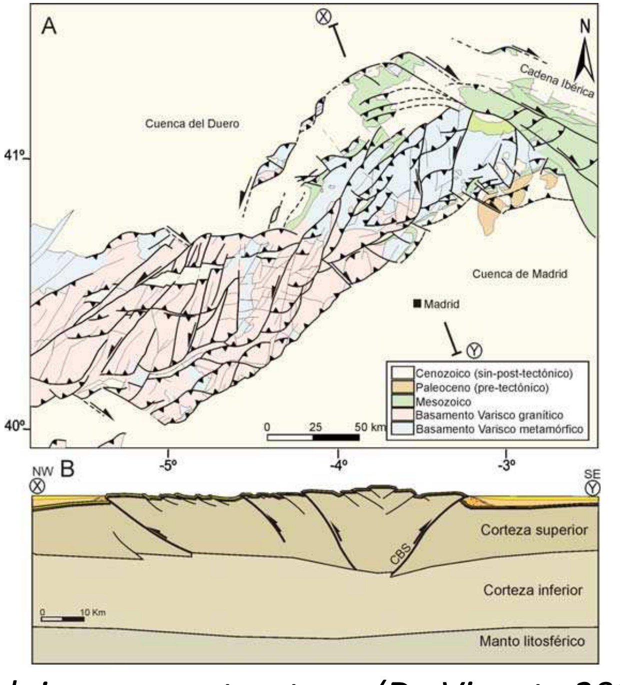
A conventional granite produces 2.65 μWm⁻³.
CS granites produces between 4.05-6.5 μWm⁻³.



Granitic Landscape Pedriza de Manzanares

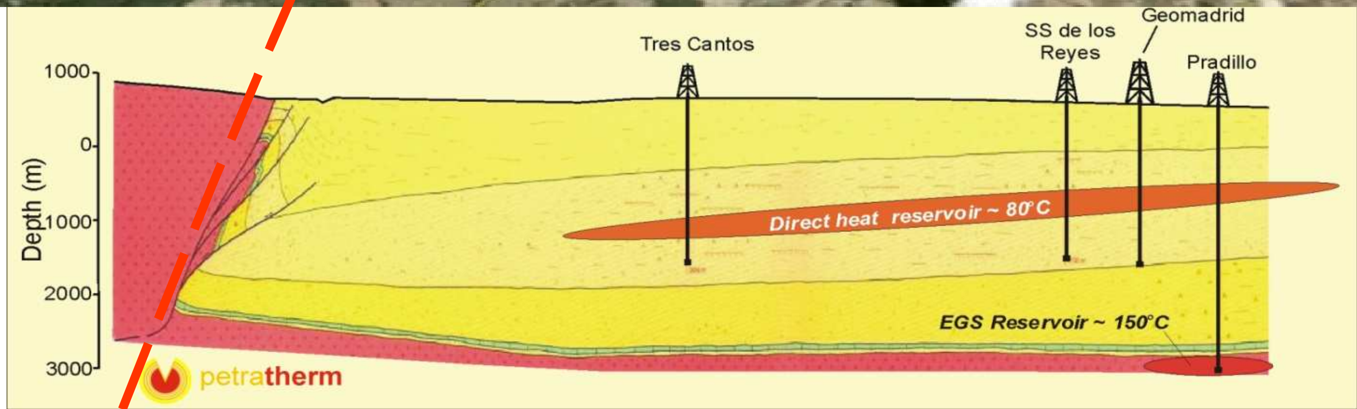
Those values create anomalous heat flow values of around 100 mWm-2

Another hypothesis is the SBT (south border thrust) structure acting as a trap and as "deep heat circulation fluids channel" (De Vicente et Al 2008)

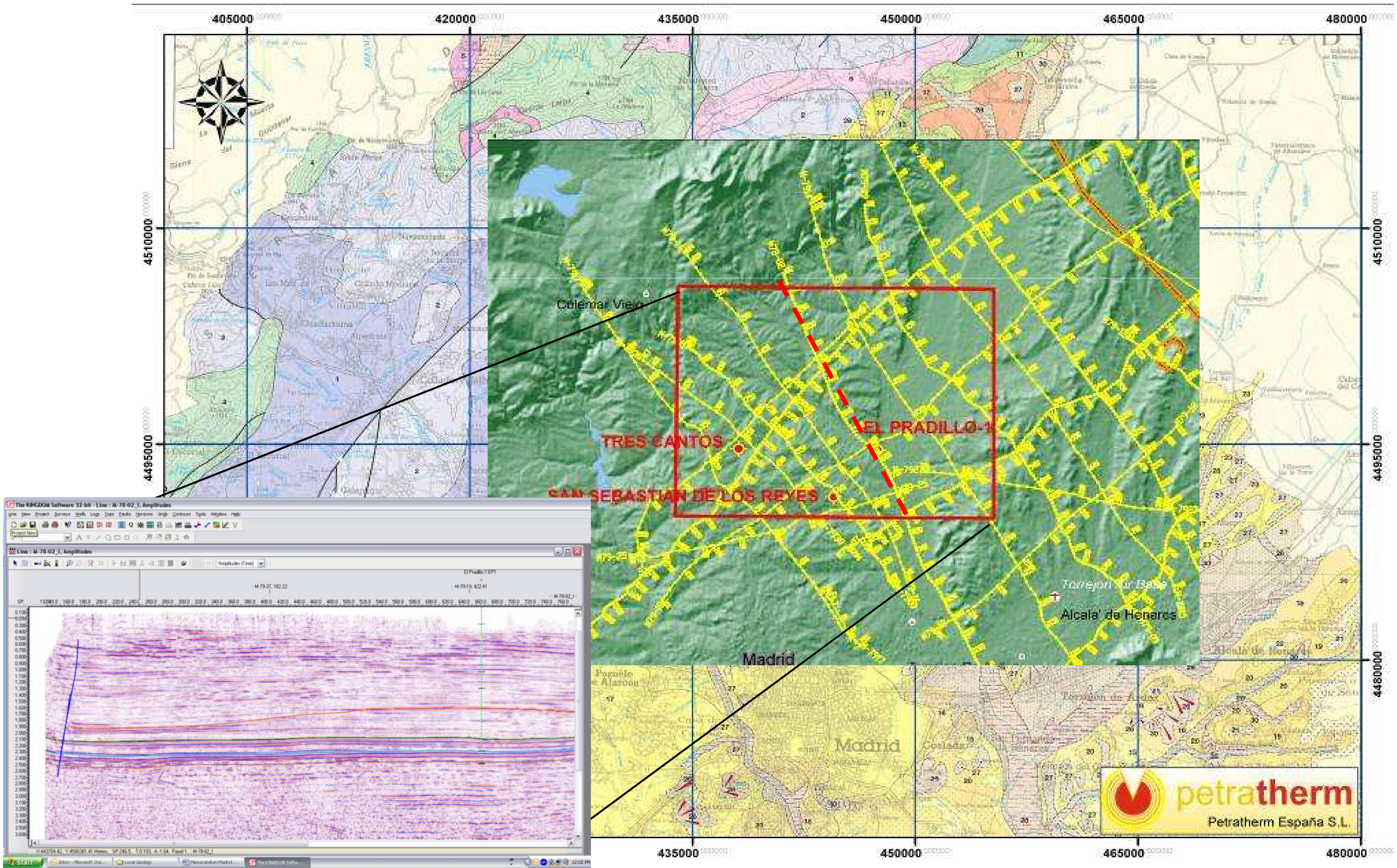


CS alpine macrostructure (De Vicente 2007)

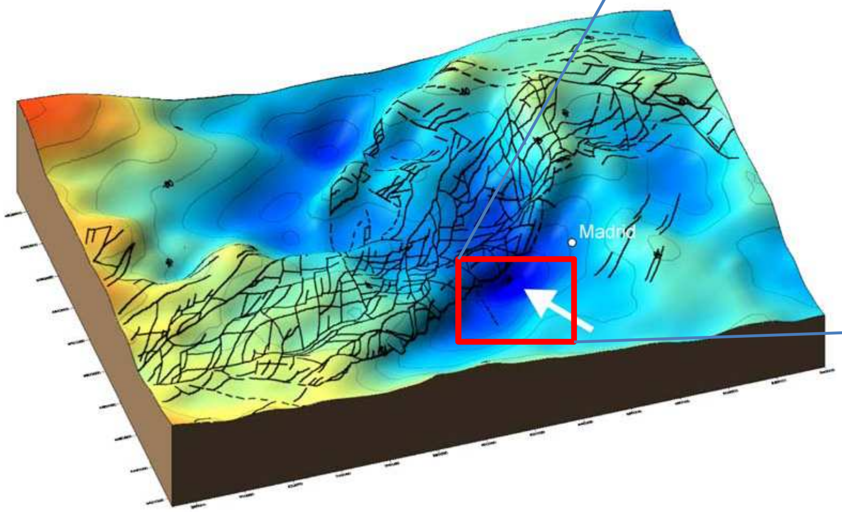
A very valuable drilling information

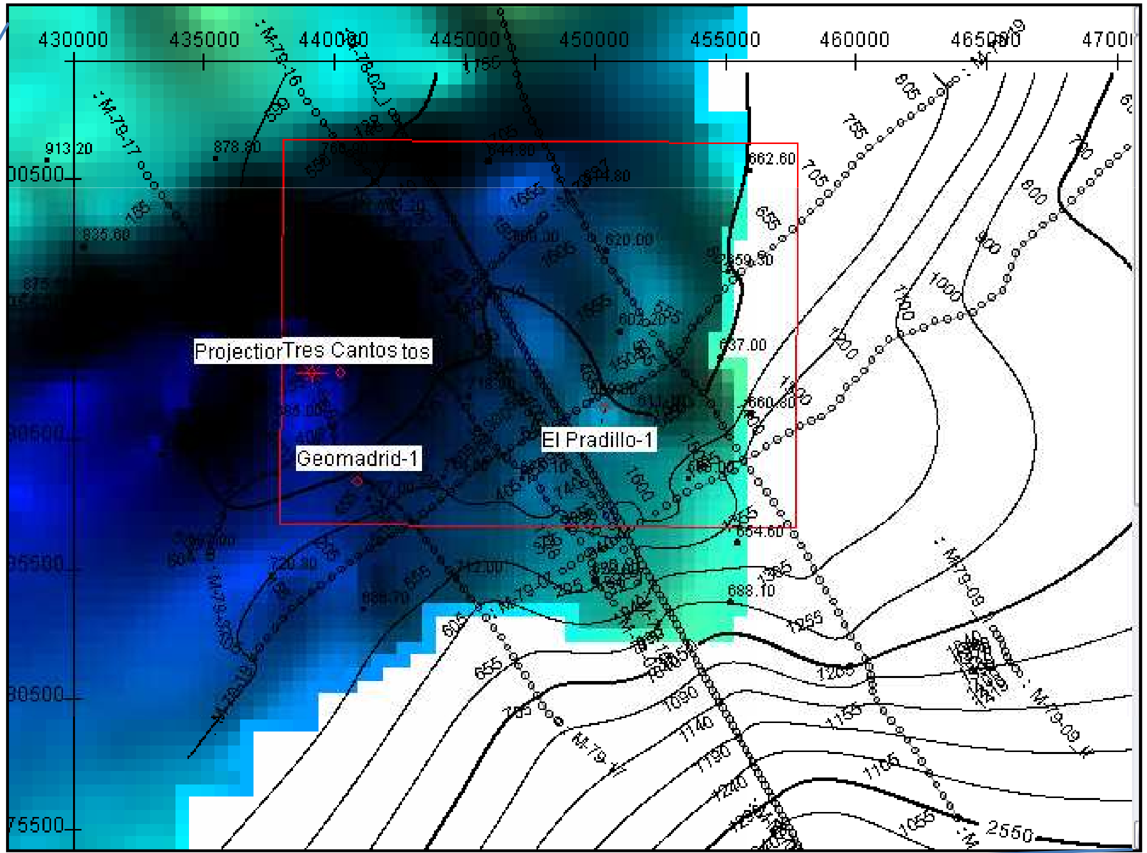


Basin structure interpretation



Basin structure interpretation



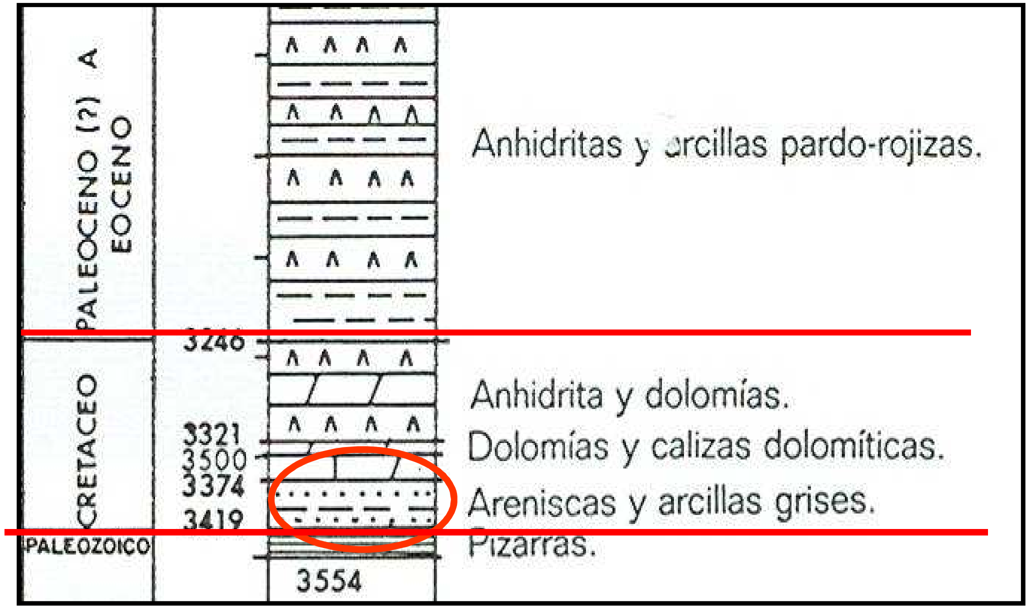


Detailed NW limit Madrid basin Petratherm structural model

CS Gravity 3D model showing the SBT (A. Martin 2004)

Potential deep mid temp. reservoir

- Some temperature tests were done at 3,400m within the cretaceous formation (150-200mts) obtaining extrapolated temperatures of 150º and low permeability.
- Due to the fact Pradillo was an oil well, no drilling was undertaken within the basement.
- No information about temperatures and permeability on the basement available.
- Great potential associated to the Cretaceous formation or to the fractured granitic basement.



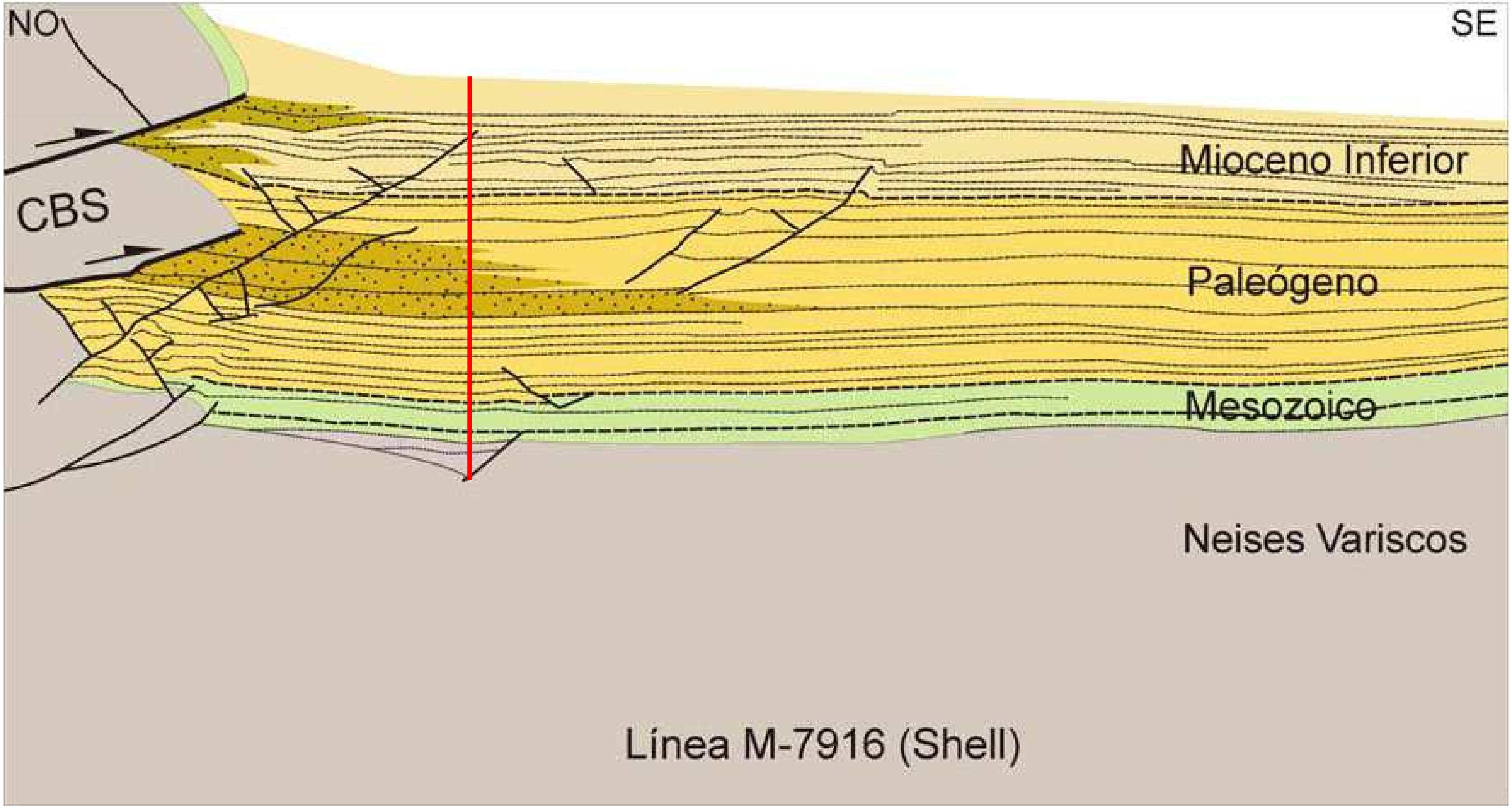
RESULTS (IGME 1981)

Permeability k: 9,3 md

Extrapolated temperature: 150ºC

Salinity > 60g/T

Potential deep mid temp. reservoir



Seiismic Line M-7916 from Shell reinterpreted (G. De Vicente et al 2008)

Conclusions medium temp reservoir

Detailed Structural model definition

Location of areas of higher depth on the basin 3500-4000m depth.

To be addressed

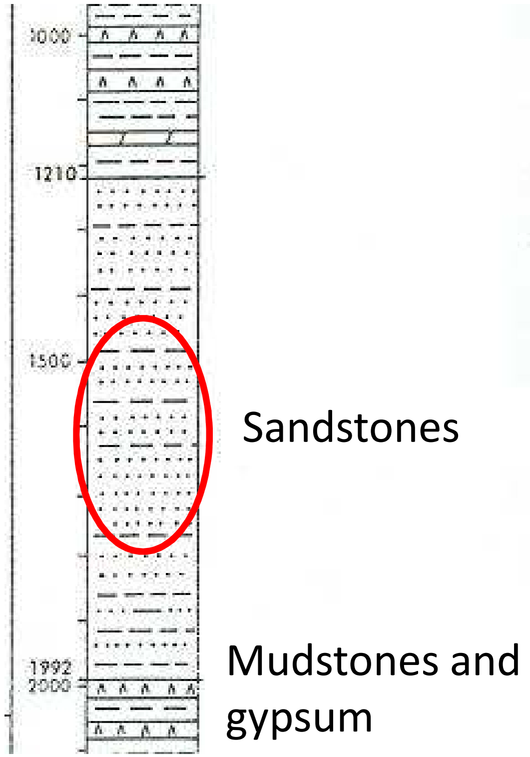
Definition of a detailed thermo-mechanical 3D model

Launch of a demonstration project in Madrid to proof of concept

- Definition of the target areas
- Geothermal exploration well
- 2nd Geothermal well
- Circulation test
- Pilot plant
- Initial estimated investment 30m €

Low temperature reservoir potential

- Pradillo well identified temperatures of 88ºC at 1750 m depth alongside fair permeability. Several flow tests(DSTs) were undertaken within the sandstones inferring production flow rates above 150 m3/h
- This potential, detected on an oil exploration well, led IGME to carry out a detailed plan aimed at investigating the potential of the low enthalpy reservoir north of Madrid.

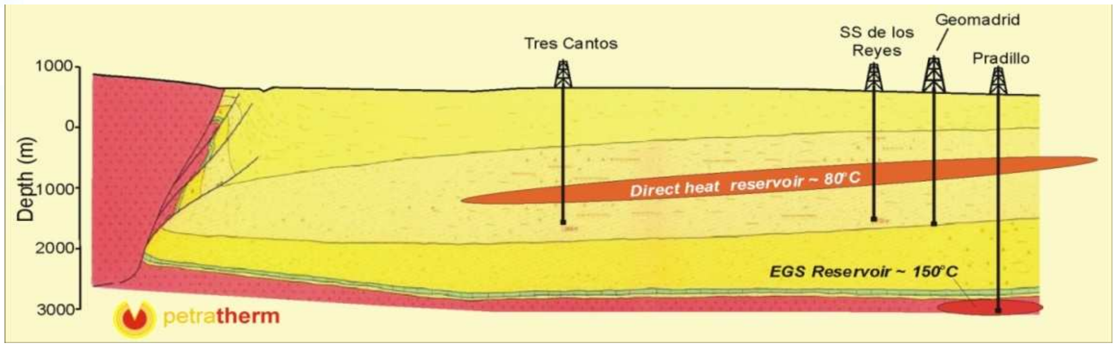


RESULTS IGME 1981)

Permeability k: 1.295 md

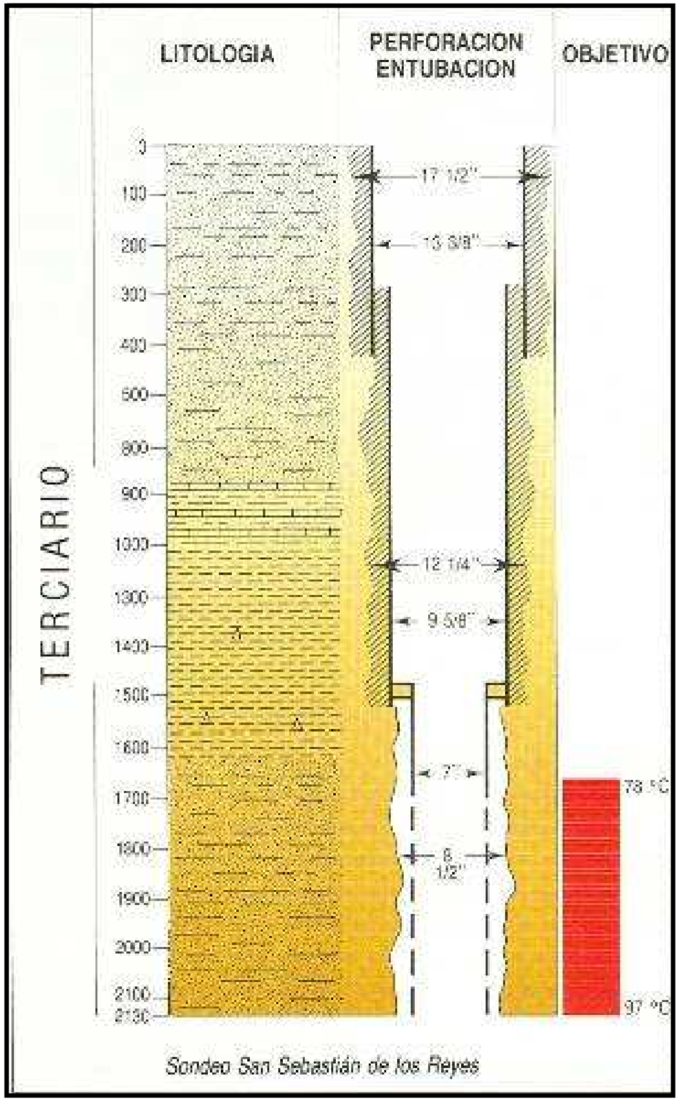
Average ReservoirTemperature: 70 – 80 ºC

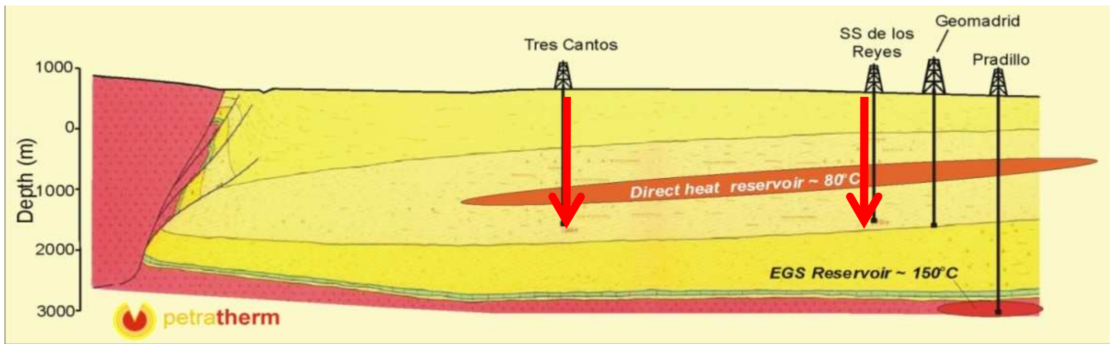
Salinity 20.000 – 30.000 ppm



IGME 1980-1985

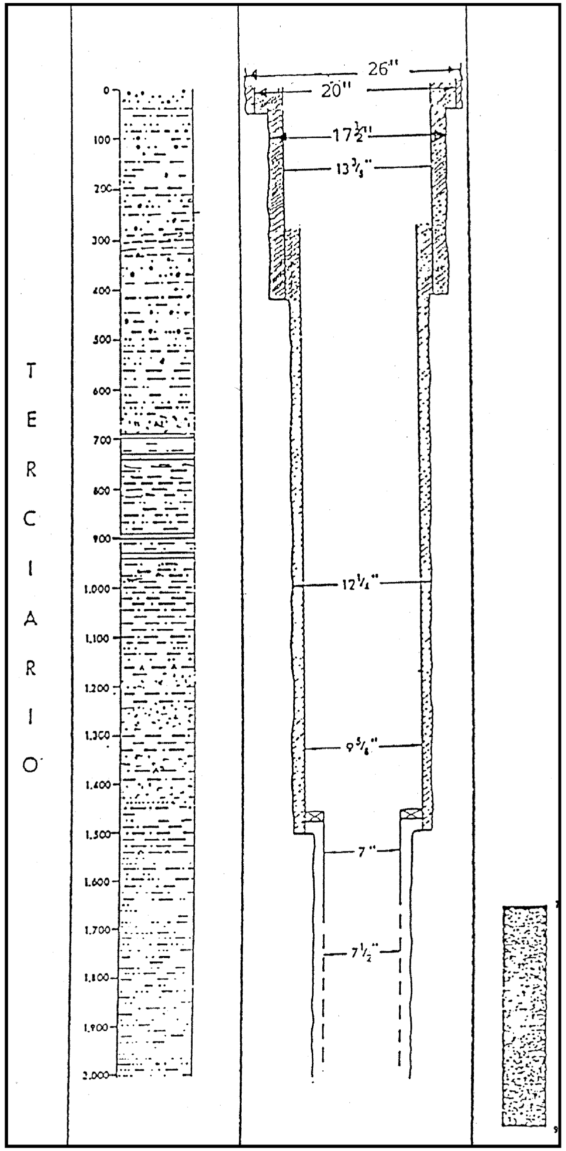
- From 1981 to 1982 an IGME-ENADIMSA JV completed two geothermal wells ca 2000 m deep, displaying promising results regarding formation temperatures and well performance:
  - Average temperatures 80ºC
  - Average production flow rates 200m3/h
  - Average depths 1700-2000 mts
- In 1985 a tentative feasibility study for a geothermal district heating grid was undertaken.
- Energy prices and institutional support not favourable to develop a project





Geomadrid project 1990-1993

- From 1988 to 1993 was initiated a new GDH project promoted by the Madrid Regional government
- A study of the resource to demand adequacy was launched in order to optimise the best project location
- The area selected was Autonoma University campus due to the high heat demand of the surrounding buildings and favourable(access, lengths) distribution grid requirements .
- Geomadrid 1 well was completed in 1990
- Geomadrid 2 was abandoned in 1993 further to severe drilling failure(stuck BHA) at 1200 mts depth.



Geomadrid 1 section

GEOTHERMAL RESOURCE CLASSIFICATION VS DEPTH, TEMPERATURE & AQUIFER OCCURENCE

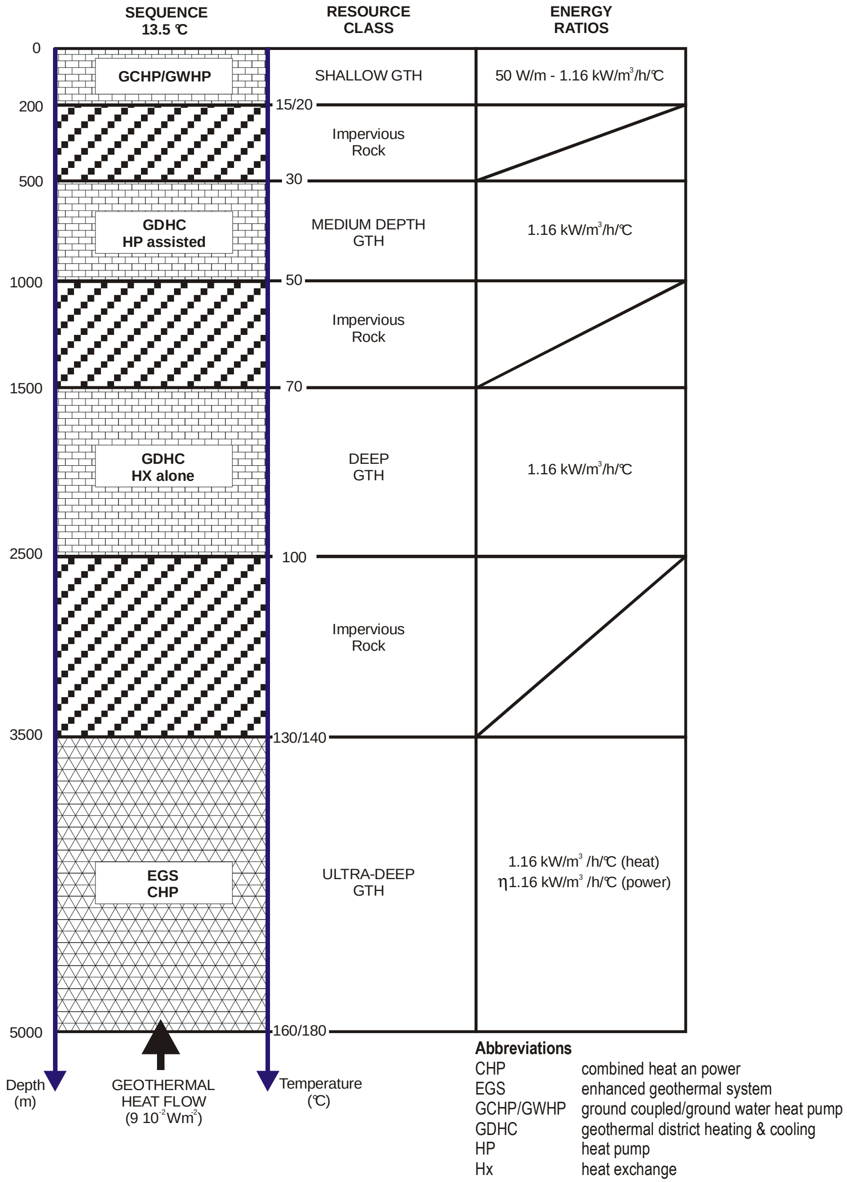
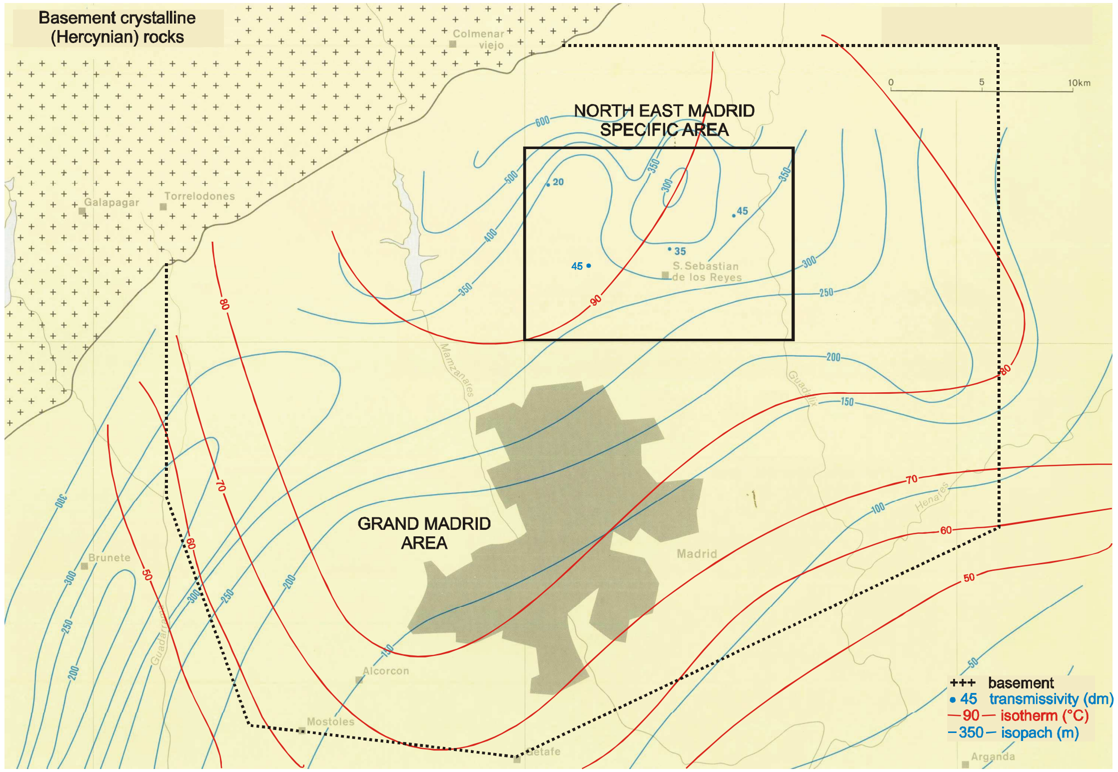
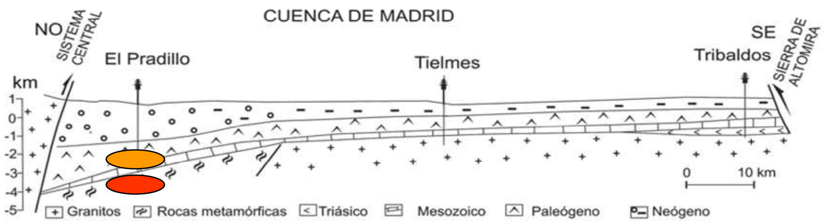


Figure 3. *Resource classification vs. depth, temperature and aquifer occurrence*

Location of Target Assessment Areas





NO-SE CROSS SECTIONAL SKETCH

(Adapted from European Geothermal Atlas & Racero 1988)

Preliminary Geothermal resources clasification

Item	Grand Madrid	NE Madrid
Heat in place (HIP) 10^{18} J	181	22
Recoverable heat (RCH) 75 yrs 10^{18} J	25	3.5
Exploitable heat (and power) (EXH) 75 yrs 10^{17} J	7.3	1.7
Heat resupply (assuming 90mWm^{-2} heat flow density) 10^{17} J	3.09	0.33
EXH / RCH ratio (%)	3	5

From Ungemach et al 2008

Geomadrid Pre-feasibility Study

- In 2008, after granting the mining exploration licenses in late 2007 and using, as an example the Paris basin experience, Petratherm carries out a pre-feasibility study to define the technical and economic viability of a GDH project to the north of Madrid to produce heat, cold and sanitary hot water

- Among the various prospects investigated, Geomadrid and S.S. de los Reyes proved the most favourable due to the potential heat demand and local reservoir performance

- A thorough feasibility study has been launched for the Geomadrid site in order to appraise full project, the first GDH project in Madrid could be in operation at the end 2011

Resource Parameters vs Demand

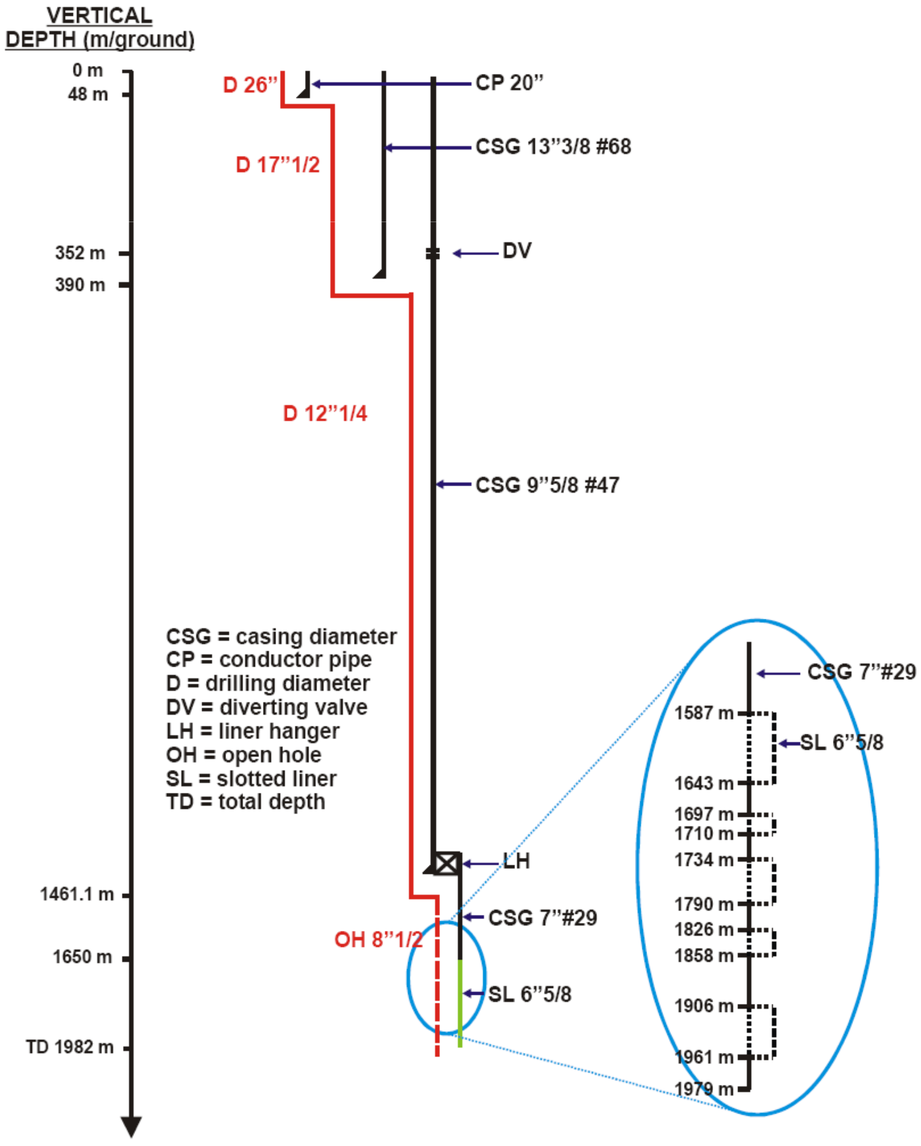
Well	Tested interval (mbgl)	Transmissivity (dm)	Bottomhole temperature (°C)	Well deliverability (m^3/h)
Pradillo	At 1600 - 1800 m	46.6	70º-80º	150
Tres Cantos	1600 - 2400 m	20.3	70º-90º	150
San Sebastian de los Reyes	1600 - 2100 m	35.3	75º-90º	250
Geomadrid 1	1550 -	44.4	70º-78º	200

Project	Heat load (MWht/yr)	Cold load (MWht/yr)	SHW supply (MWht/yr)	Total load (MWht/yr)
Cantoblanco (Geomadrid)	38400,00	5050,00	13430,00	56880,00
San Sebastian de los Reyes	44785,00		7353,20	52138,20

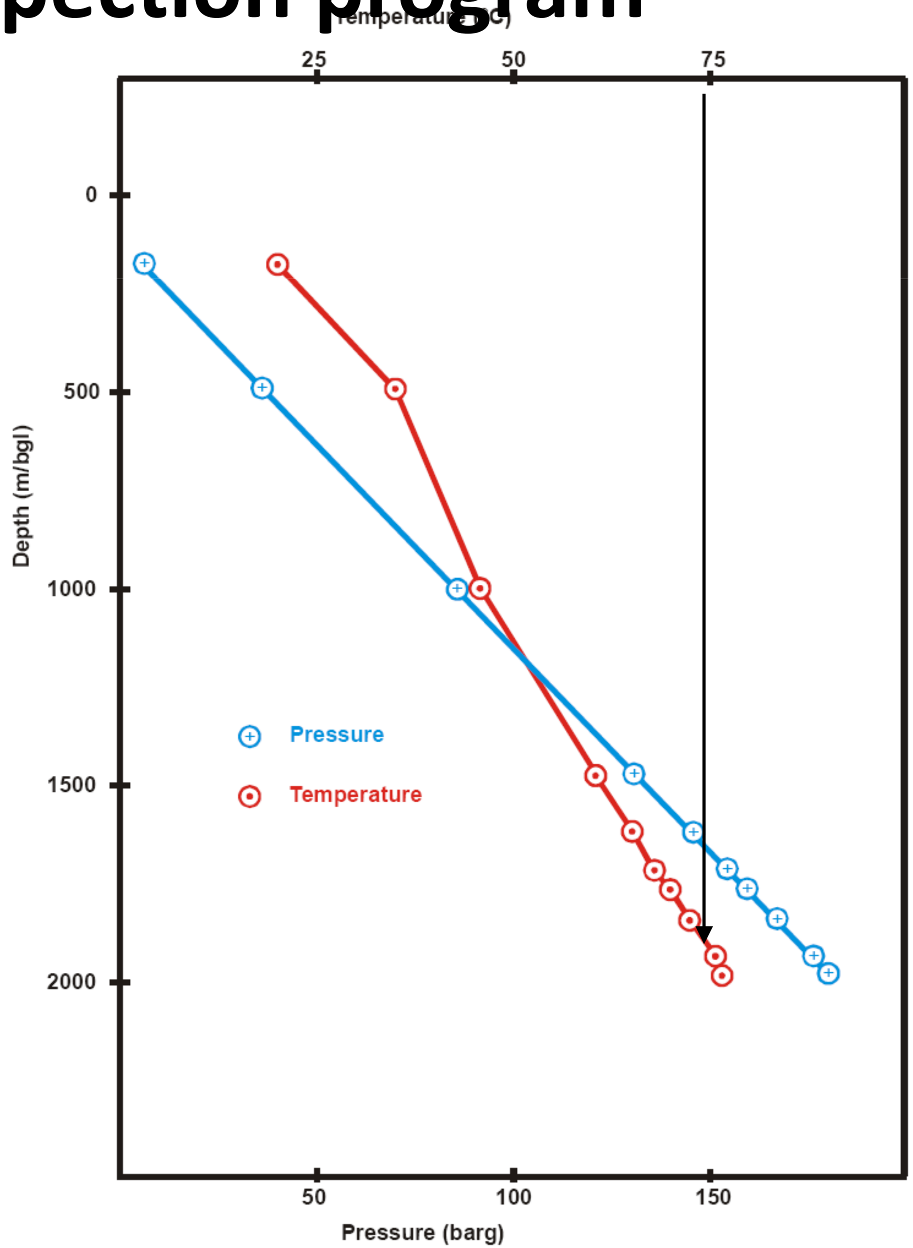
Geomadrid well logging inspection program

- A detailed well inspection program was conducted in July 2008 corroborating all the well parameters measured in 1990.
- Logging inspection confirmed the Geomadrid well is in good shape and can be integrated to the new doublet thus achieving a significant cost saving.

Geomadrid well logging inspection program



Reconstructed Geomadrid 1 well profile.



P/T profile

Conclusions Geomadrid GDH Prefeasibility study

- A realistic projection over the specific northeast Madrid area would estimate at ten the number of GDHC doublets which could effectively be operated locally (Geomadrid: 2; San Sebastian de los Reyes:3; Tres Cantos:2-3;other locations:2-3).

- Assuming a unit doublet production of 40,000 MWht/yr (144,000 GJ/yr), total heat withdrawn from the tertiary sandstone aquifer over 75 years would amount to 30 TWht (i.e # 110 PJ) for the specific area alone.

Feasibility Study Phase

In July 2008 after the detailed well logging at Geomadrid, a decision was taken to undertake a full feasibility study program.

- Detailed heat demand study of the potential users of the energy
- Engineering design of the most favourable solution
- Establishment of an economic business plan.
- Secure the demand (long term contract commitment form the final users)

The study has being almost finalised in june 2009 with positive results

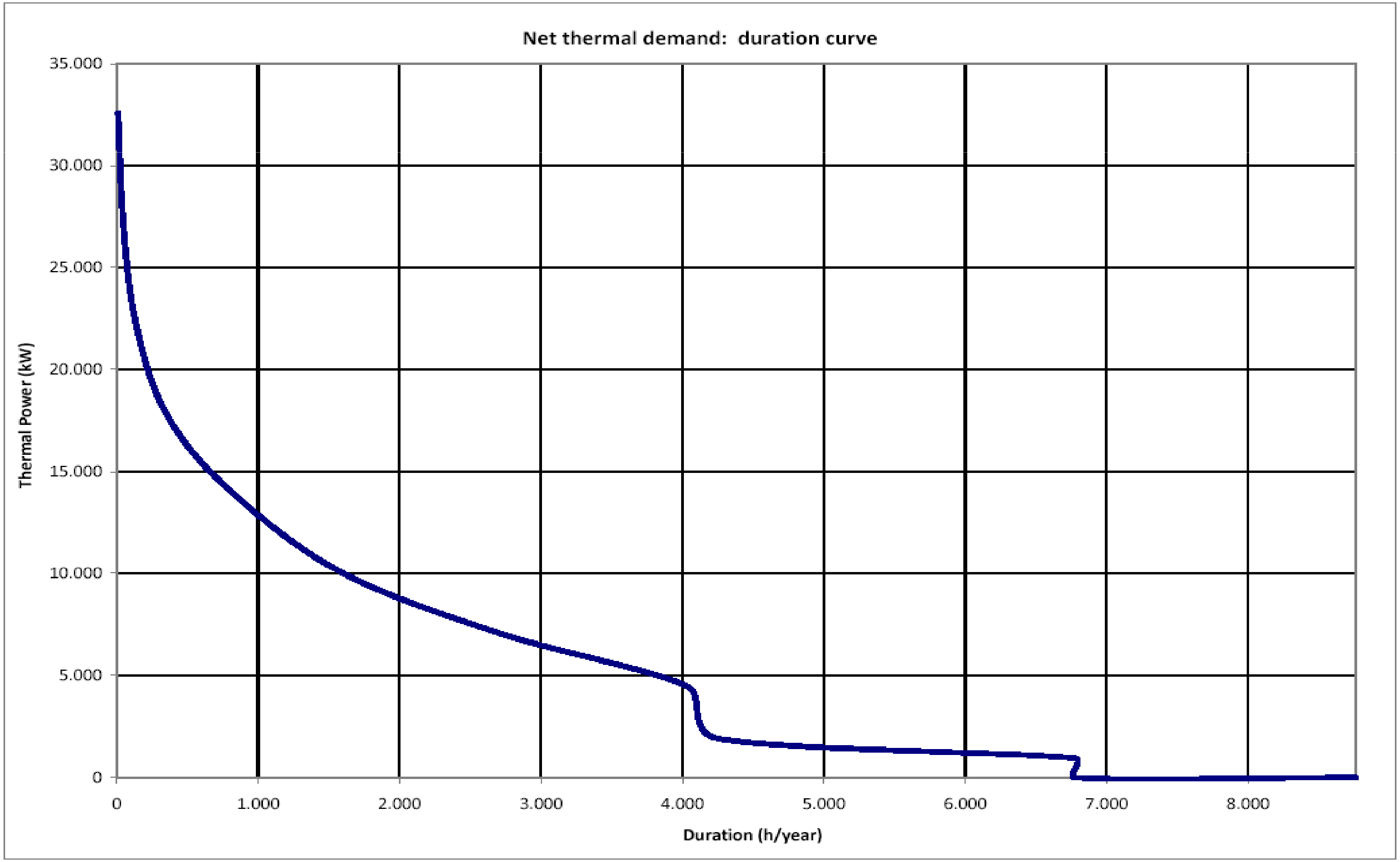
The federal gov, reg gov and Petratherm signed an agreement last July to promote what will be the first geothermal district heating grid in Spain.

Heat demand study

Puntos de consumo identificados:

- Universidad Autónoma de Madrid
- Residencia de Ancianos Ntra. Sra. Del Carmen
- Hospital Psiquiátrico Rodríguez Lafora
- Ciudad Escolar
- Residencia de Ancianos Dr. González Bueno
- Colegio San Fernando
- Pozo de producción de agua caliente GEOMADRID

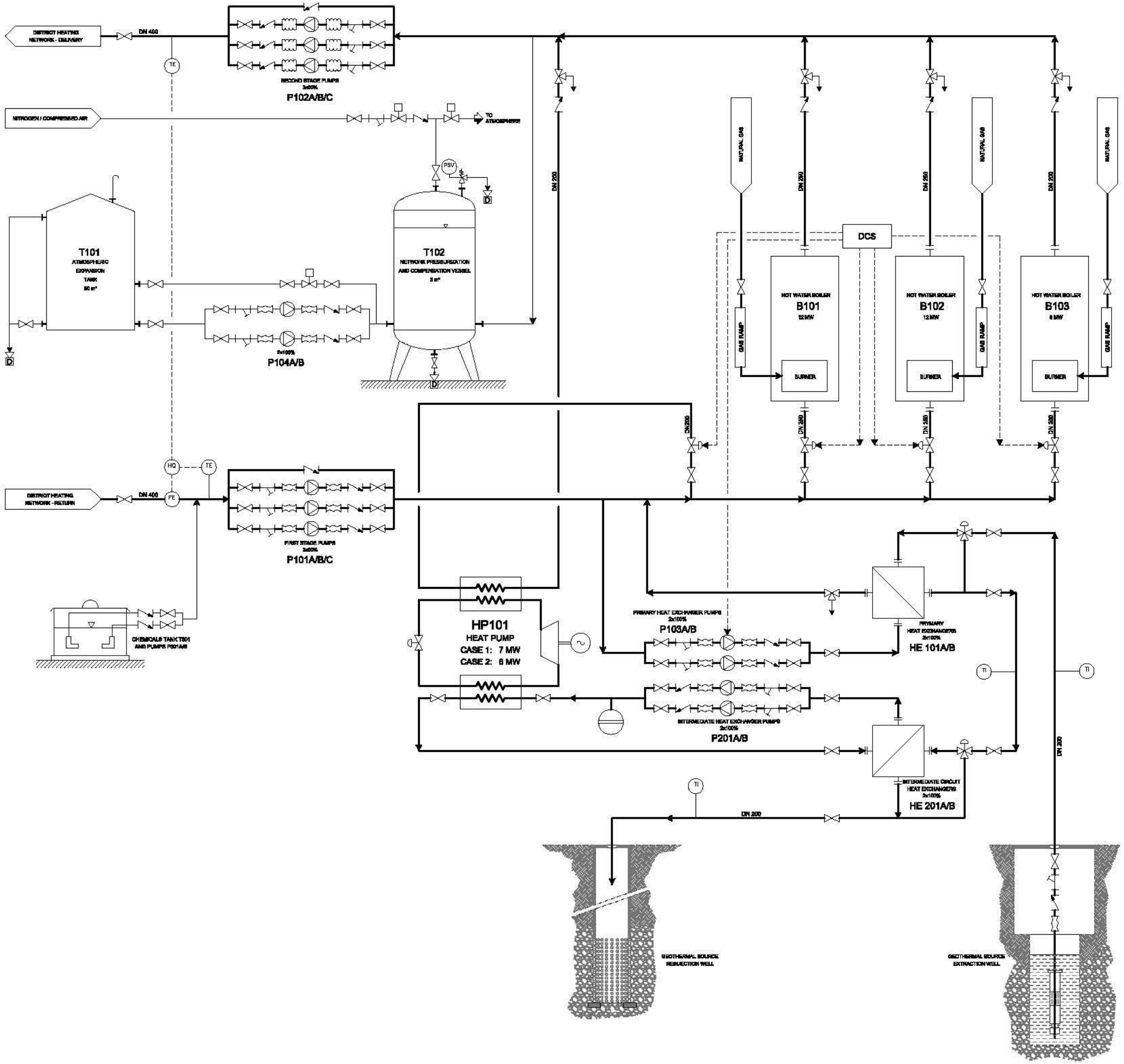
Duration load Curve and demand

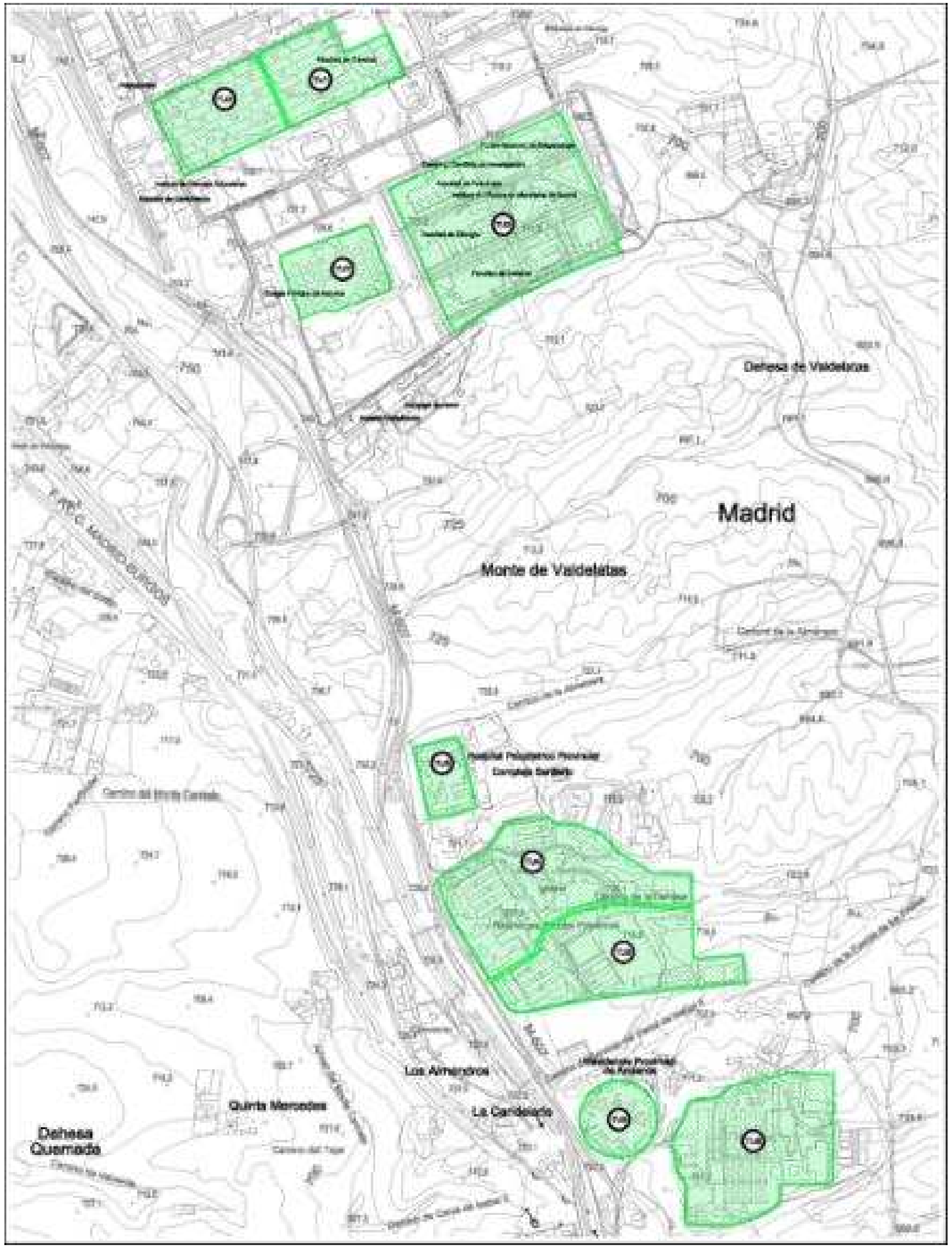


Technical solution

- Power plant : solution GPC IP – SAI
  - Geothermal well
  - Heat pump
  - Gas Boilers
- Hot water production at variable temp in function of the external temperature, transported by a grid to cover SHW and heat necesities form the buildings includded in the study
- Working Ratios :
  - **6700 h /year production primary heat exchanger**: low temp production and low power neccesities
  - **1300 h/year production primary heat exchanger+anciliary equipment** : low temp production and power neccesities above geothermal well power.
  - **136 h/year production primary heat exchanger+anciliary equipment** : Heat exchanger temperature below the demand
  - **28 h/ año producción pozo geotérmico + auxiliares**: Heat exchanger temperature amd power below the demand
- Primary heat exchanger covers one third of the total heat demand

Design Basic engenieering solution





USERS INVESTIGATION

GENERAL PLAN

LEGEND	
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

Geomadrid project key parameters

- Resource Temp. 75ºC
- Reservoir depth 1500-1800m
- flow 200m^3/h
- Installed power 8MWt
- Power production 38,000MWth/a
- Distribution grid 4 Km
- Substations 9
- Investment 12-14M€
- District heating and HSW equivalent to 5.000 dwellings
- save 3.000 TOE/a
- Reduction de 6.000 CO_2 Tn/a
- To be in production in 2011

Thanks for Your Attention

Deep geothermal energy potential in the Madrid Basin

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Key words: Madrid, geothermal, low temperature, thermal uses

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 fig. 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 fig. 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.

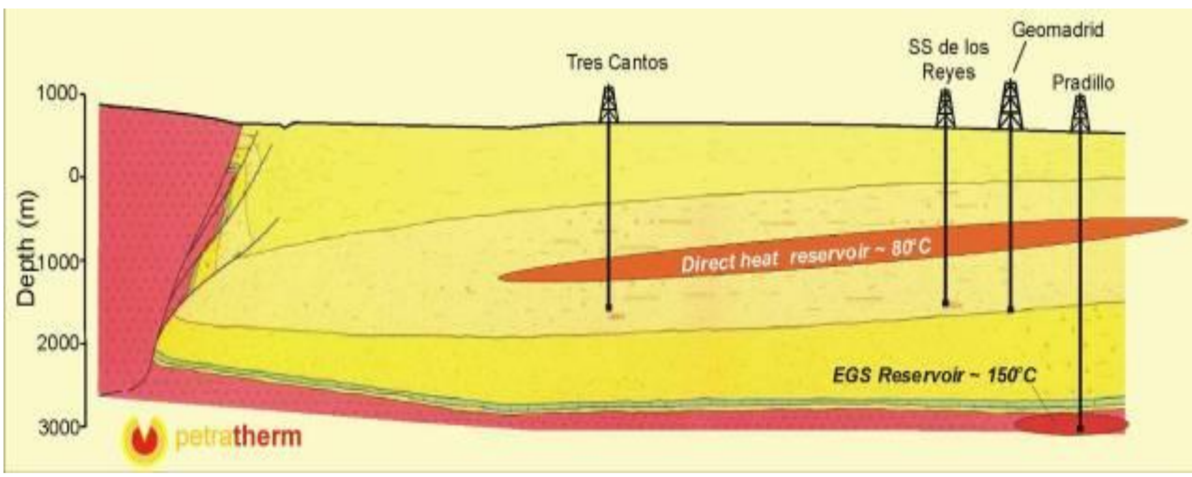

Figure 1.-Madrid Basin N-S section, modified from IGME showing the position of the geothermal wells

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) (fig. 1)

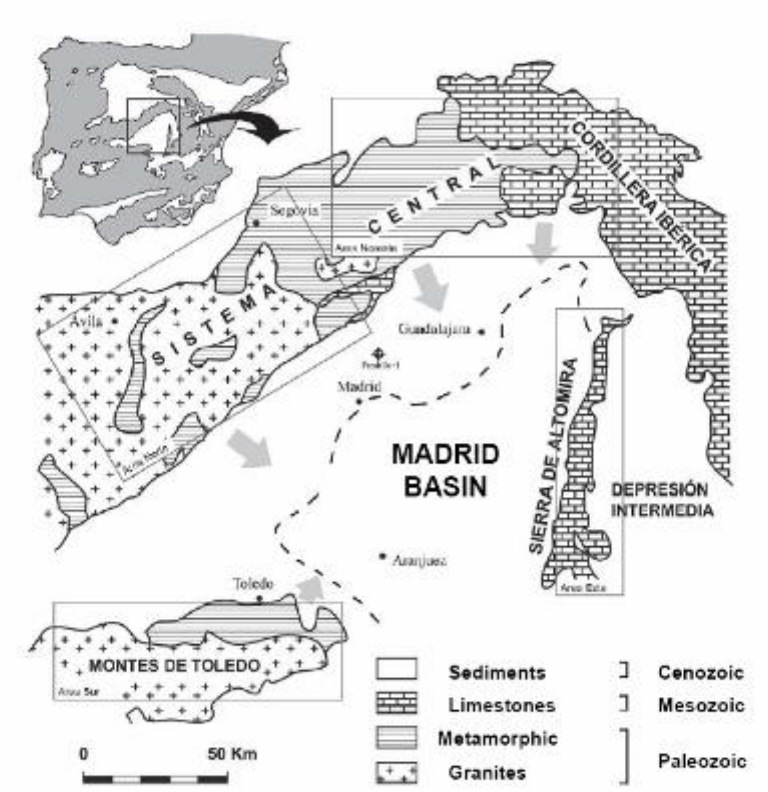

Figure 2.- Madrid Basin structure modified from Calvo et al (1989)

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 fig. 3).

The highlights of the low enthalpy reservoir are summarised hereunder

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

Table 1.- Madrid Geothermal well summary sheet.

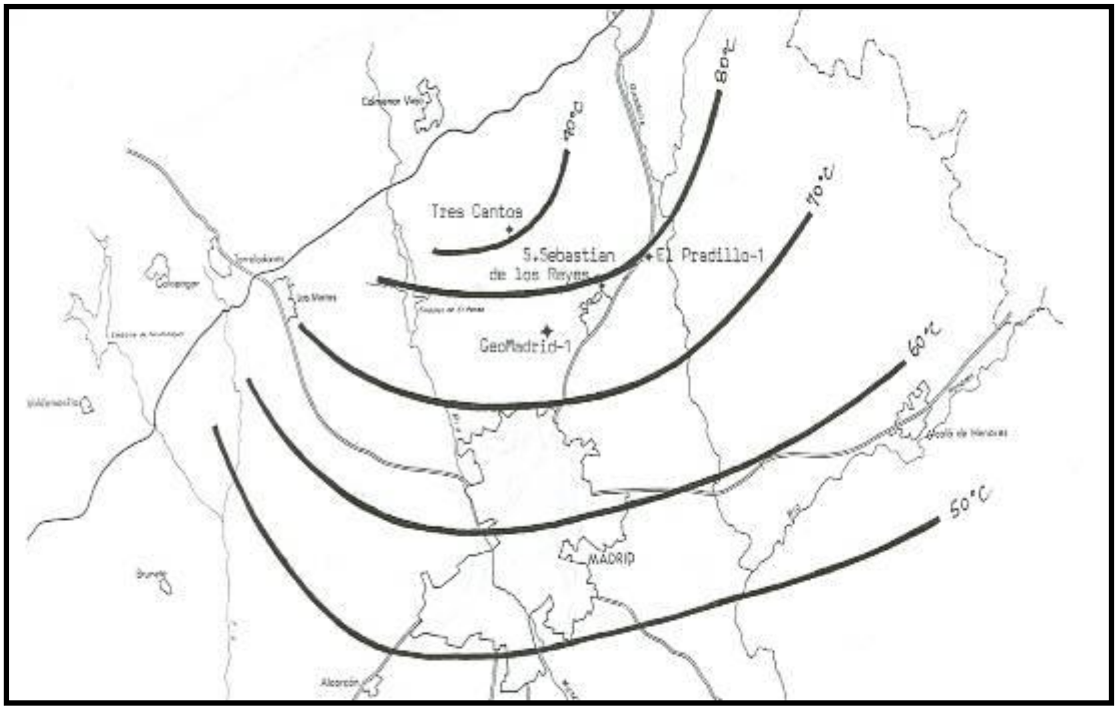

Figure 3. – Tertiary clastic, low enthalpy reservoir isotherms.

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 fig. 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 fig. 4.

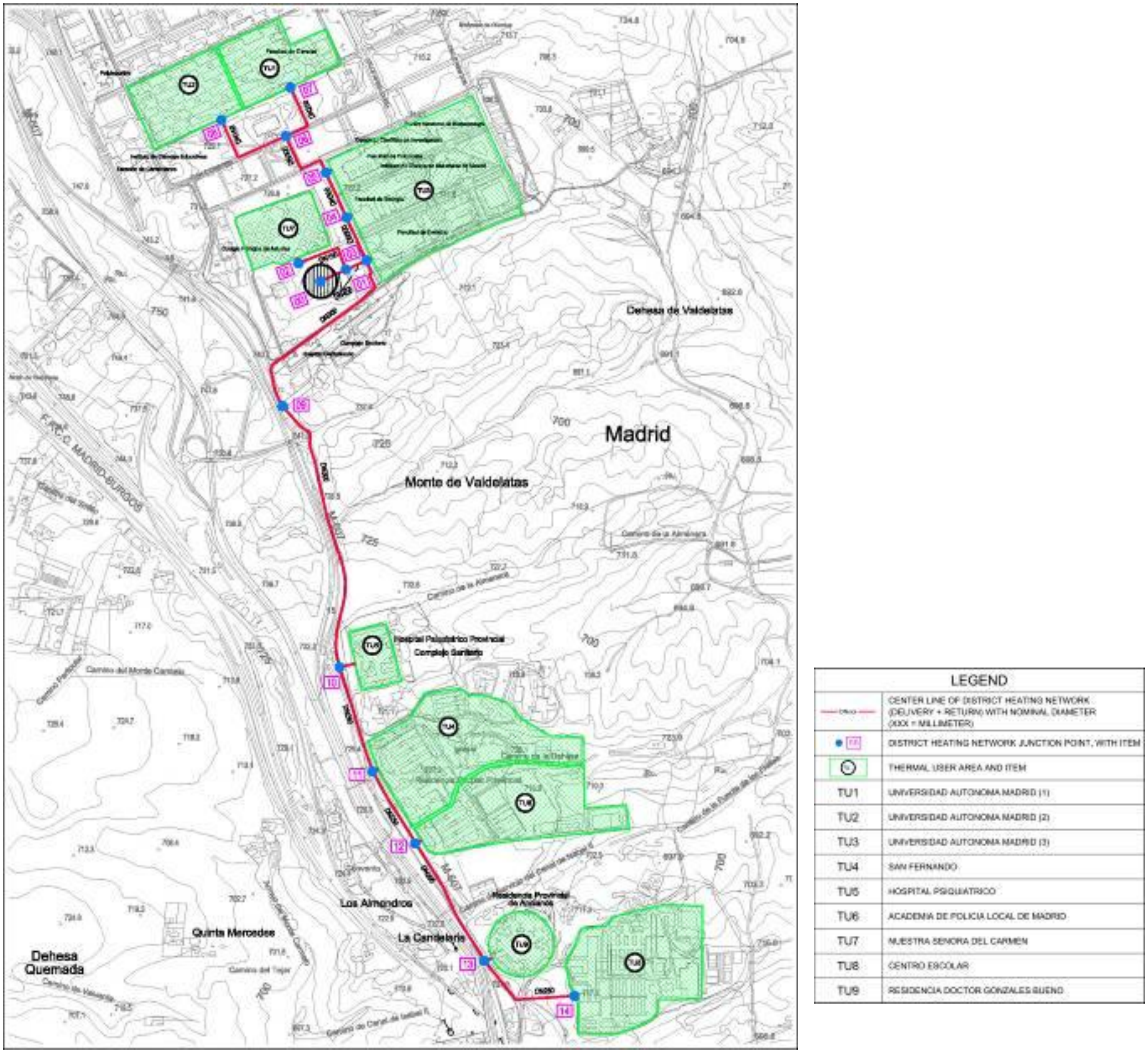

Figure 4- Planned Cantoblanco/Valdelatas district heating grid

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.

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