

Geothermal Resources in Portugal

EGEC GEOELEC Workshop

Nov 10th, 2011 - Valencia

Overview

- Current situation / Geothermal potential
- LNEG/LGM
- Available data
- Geothermal Research - ongoing activities
- what is missing

Geothermal Resources in Portugal

Superficial (conventional):

- Thermal water for direct use;
- Power generation in active volcanic
- Heat pumps for heat & cooling;

Deep (non-conventional):

- Power generation in various geological settings
(Enhanced Geothermal Systems – EGS)

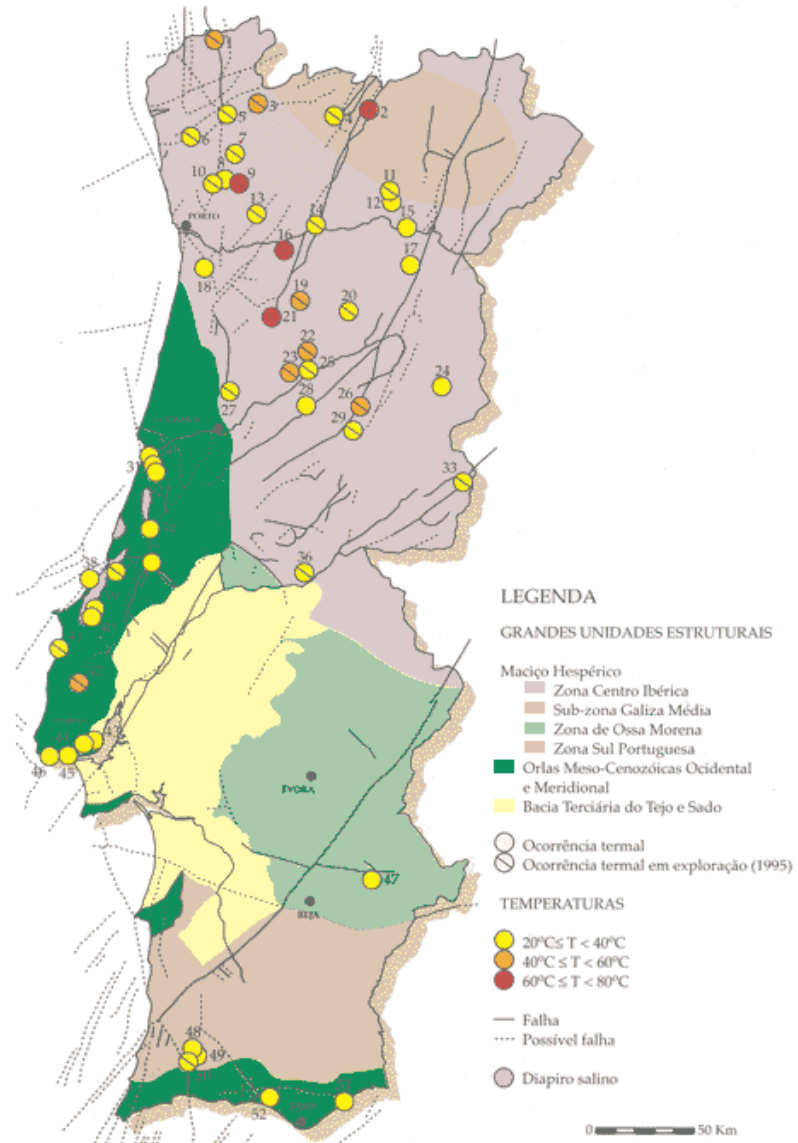
+ evaluation costs

> resource

Geothermal Potential (Mainland)

Low-enthalpy

- The distribution of low enthalpy geothermal occurrences in Portugal cover the entire country unevenly but rather intense.
- Geothermal explorations have been increasing in number, mainly confined, however, for thermal springs.
- The geological characteristics of the country enhance the existence of other low enthalpy geothermal exploitable places.

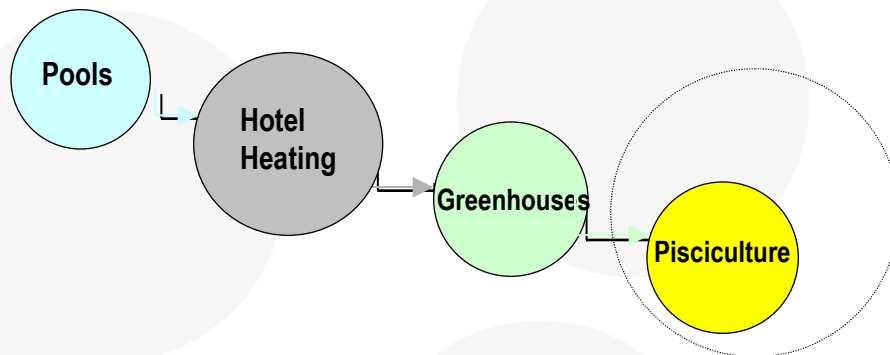


Geothermal Exploitation (Mainland)

Low-enthalpy – Direct Uses

➤ Lisbon – Air Force Hospital (since 1992): a geothermal well (1500 m depth. and 50 ° C) for the production of hot water, air conditioning and cold potable water;

➤ Chaves: a well (AC2 – 149 m depth 76° C) of the spa is used for heating water in the public pool, space heating in the hotel and, finally, the heating of greenhouses located 4 km from the resort, in a waterfall utilization.



Greenhouse heating with water from AC2.

Geothermal Exploitation (Mainland)

Low-enthalpy – Direct Uses

- S. Pedro do Sul (63° C): A geothermal exploration is operating since 2001, to heat a spa and two hotels. Nearby (Vau), there is a geothermal application in agriculture, to heating greenhouses of tropical fruits.



Vau – Test flow in a hole



Greenhouse of pinaples and bananas

- Region of Lisbon and Tagus Valley (LVT) were registered temperatures of:
 - 30° C in natural occurrences (Lisbon and Vila Franca de Xira);
 - 50° C in cores of 1500 m depth (Lisbon, Lumiar);
 - 56° C, in cores of 300 depth in a diapiric area (Torres Vedras)

Geothermal Potential (Azores)

Active volcanic area

S. Miguel Island (5)

- Ribeira Grande
- Pico Vermelho



Pico Vermelho geothermal

Terceira Island

Res
Low

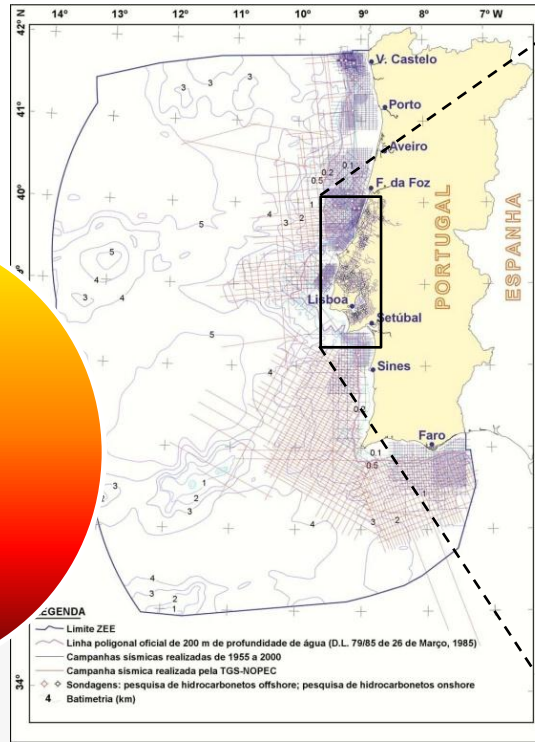
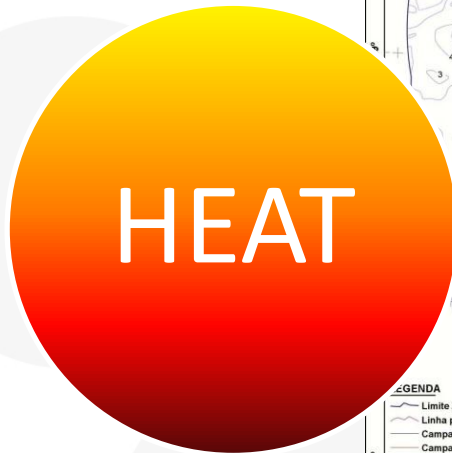
Island	Power [MWt]
S. Miguel	173,0
Terceira	25,0
Faial	8,9
Pico	12,0
S. Jorge	8,0
Graciosa	5,0
Flores	2,5
Corvo	1,1
Total	235,5

W)

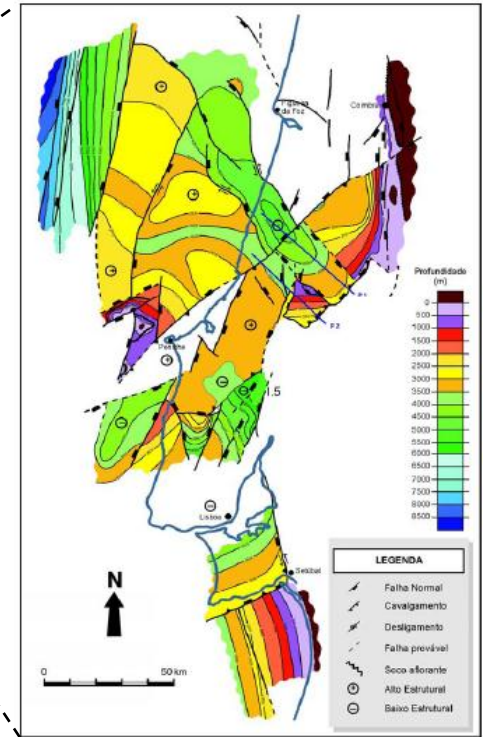
Pilot powerplant of 3 MW

Geothermal Potential (Mainland)

High Enthalpy - EGS



Dir.Geral Energia Geologia



Kullberg et al (2006)

➤ Favorable geology to develop EGS :

- Radioactive Granites
- Sedimentary Basins



Positive (?)
political/institutional
framework

Geothermal Potential

High Enthalpy - EGS

Promising areas (**Mainland**):

Trás-os-Montes

Douro

Pinhal

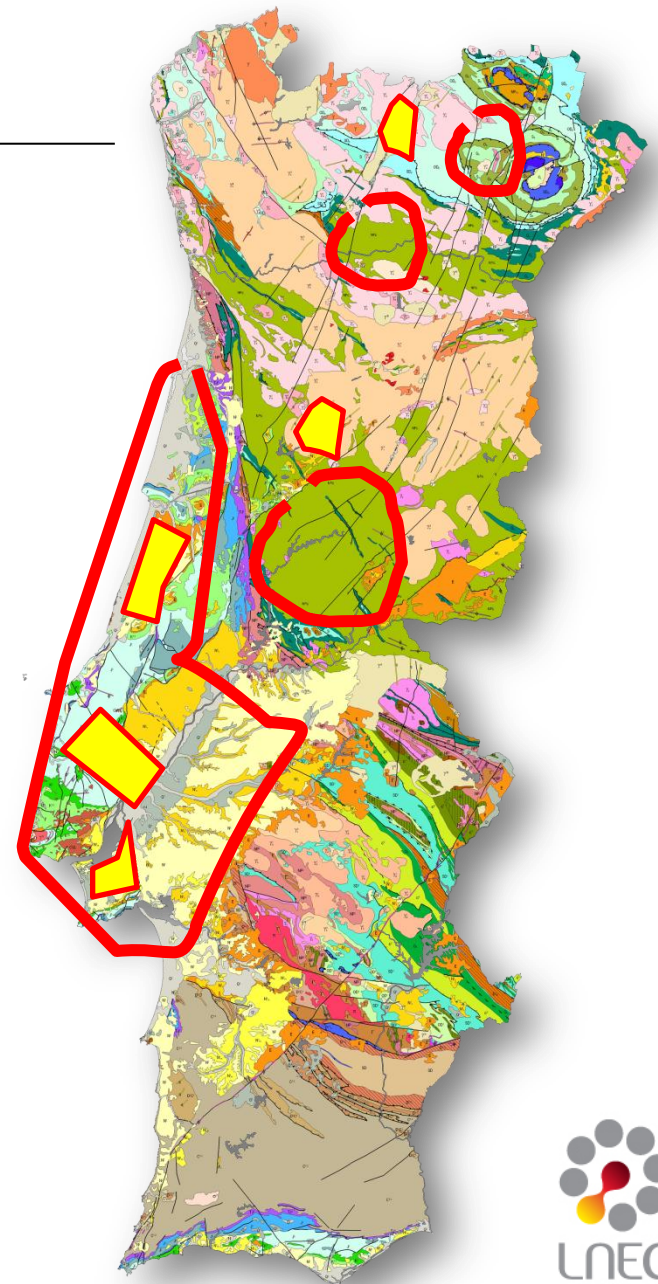
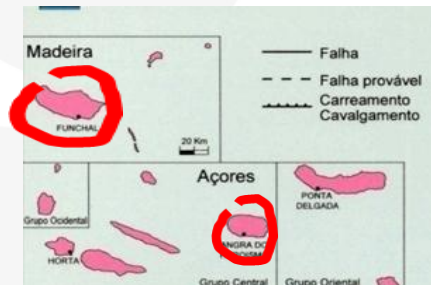
MC Basin

➤ 5 permits to private enterprises

Islands

Azores

Madeira



Laboratory of Geology and Mines (LGM)



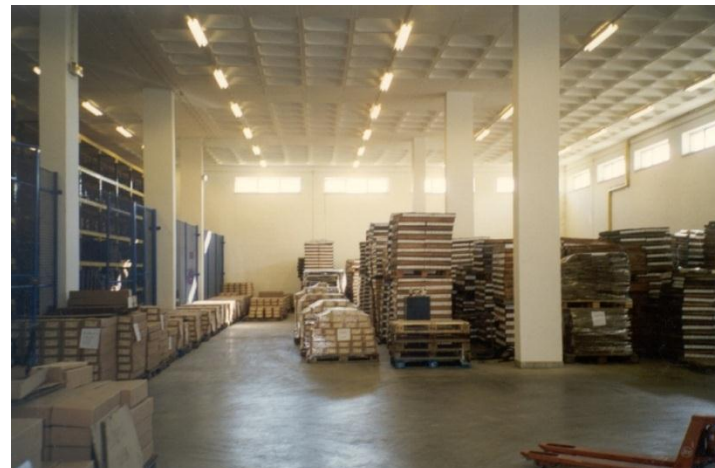
RESEARCH UNITS:

- Geology and Geological Mapping
- Groundwater
- Mineral Resources and Geophysics
- Mineral Technology
- Geosciences Information
- Marine Geology
- Drilling

Laboratory of Geology and Mines (LGM)

- Drill core storage
- Sample preparation laboratories (slabbing, gridding, sieving thin sections)
- XRD and XRF labs
- Hydrogeology lab and field equipment
- Palinostratigraphy laboratories
- Sedimentology laboratories
- Marine geology laboratories
- Reference laboratory for water analysis; microprobe; ICP-MS
- Seismic processing and interpretation lab

Drilling rigs (maximum capacity of 600 m) mobile equipment to conduct geophysical surveys (gravimetric; magnetics; seismic reflection down to 500 m and refraction down to 200 m; induced polarization; resistivity; radiometry; multiparametric geophysical borehole logs down to 600 m).



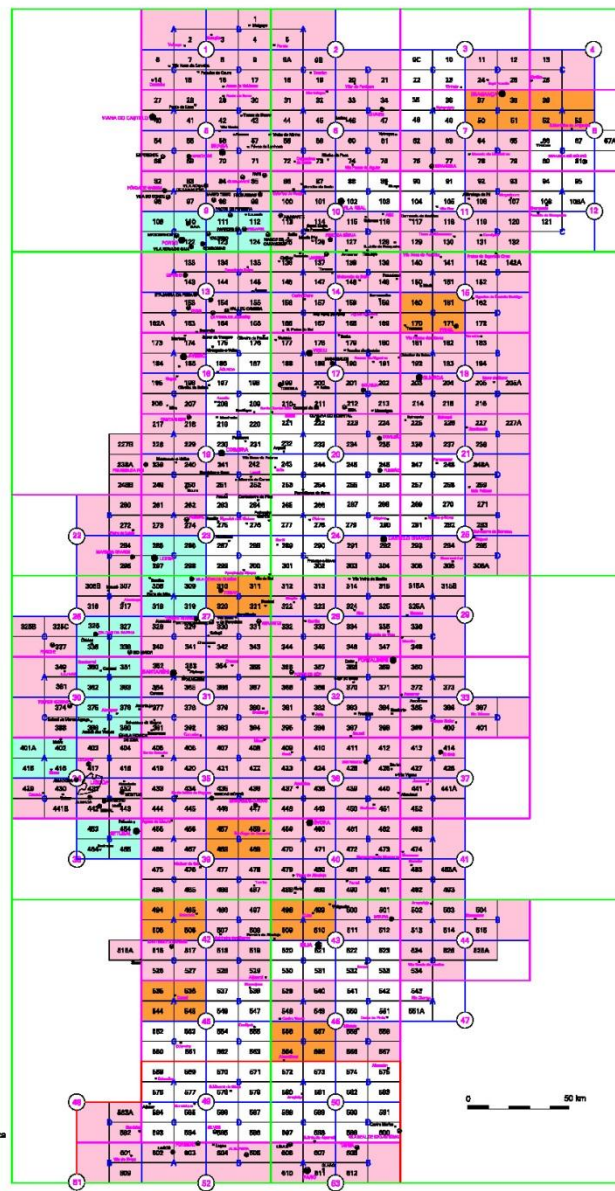
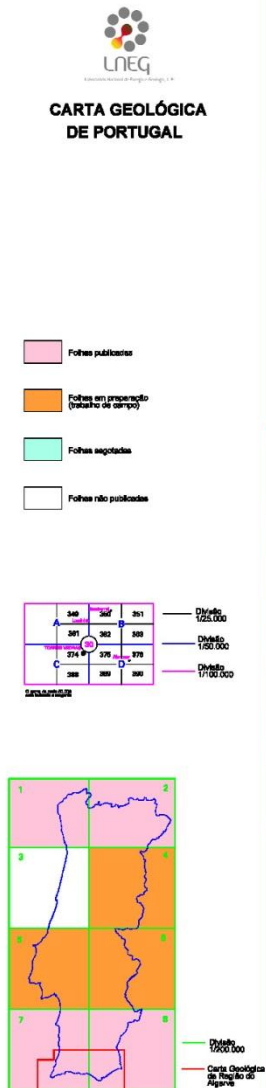
Available Data

Geological Mapping

- 1 : 50 k *in progress*
- 1: 200 k *in progress*
- 1: 500 k *comp.*
- 1: 1 000 k *comp (2010)*
- 1: 25 k *drafts*
- 1: 100 k Algarve
- 1: 10 k Lisbon county
- 1: 1 000 k Continental shelf

Thematic Mapping

- Hydrogeological 1: 100 k, 1: 200 k
- Sources and risk of contamination (Douro and Minho)
- Tectonic 1: 1 000 k
- Neotectonic 1: 1 000 k
- Aeromagnetic 1: 1 000 k
- Geomagnetic 1 : 50 k *in progress*



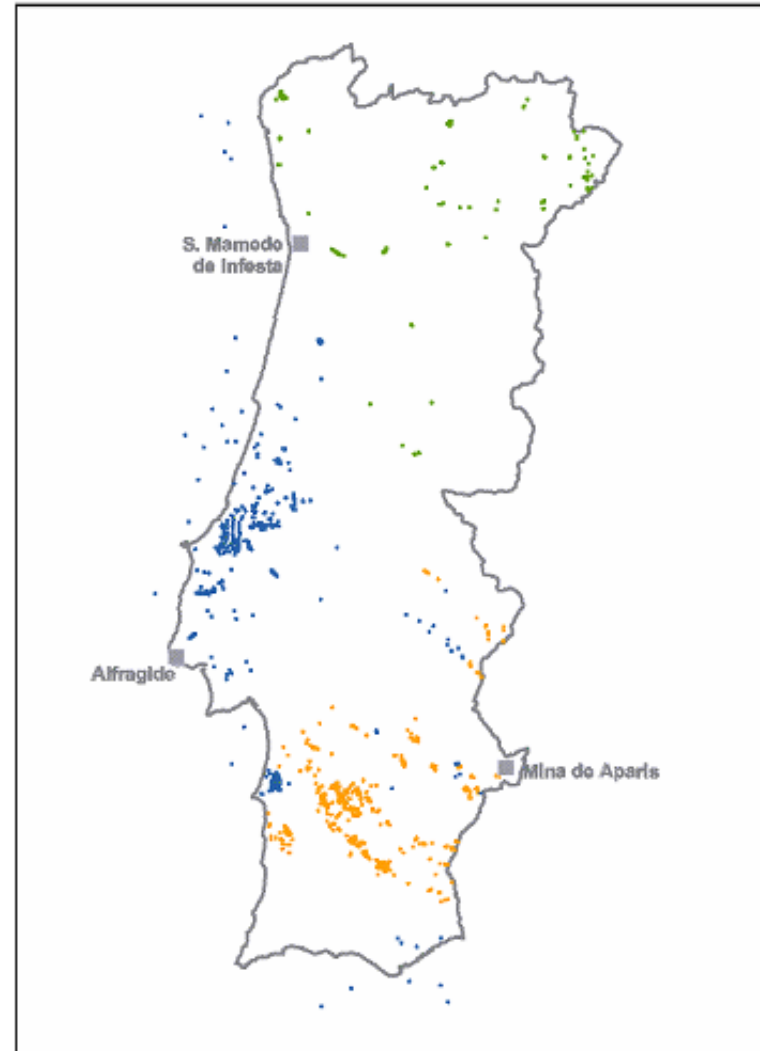
Available Data

Drill Core @ Sample Storage @ LNEG

From geological studies, oil exploration, mining research..

- Lisbon (Alfragide)
- Alentejo – Barrancos (Mina de Aparis)
- Porto (S. Mamede de Infesta)

- ~ 700 km of core samples
- Over 100 geological sections with thousands of samples, thin sections, microfossil cells and technical reports



Available Data

Drill Core @ Sample Storage @ LNEG

Lisbon

Total area	2 200 m ²
Core/cuttings storage capacity	400 000 m
Total of stored core/cuttings	638
Total km of core/cuttings stored	230



Porto

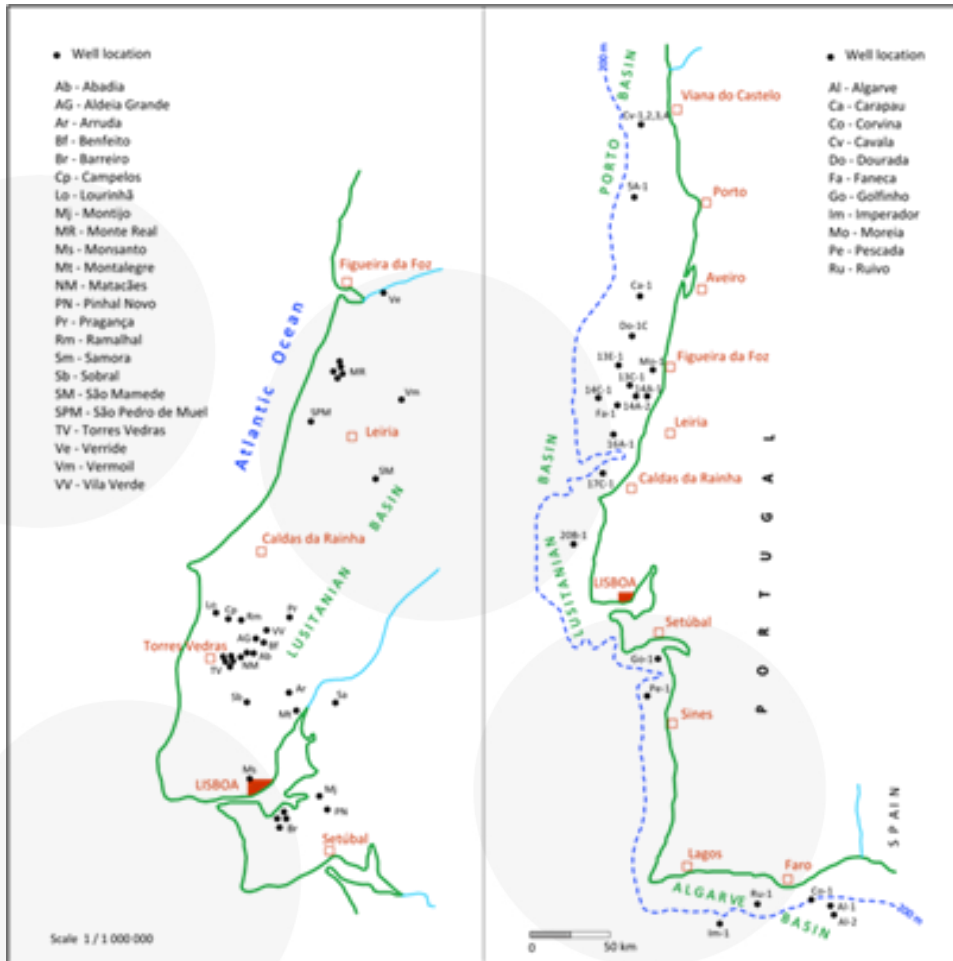
Total area	1 200 m ²
Core/cuttings storage capacity	200 000 m
Total of stored core/cuttings	730
Total km of core/cuttings stored	195

Barrancos - Alentejo

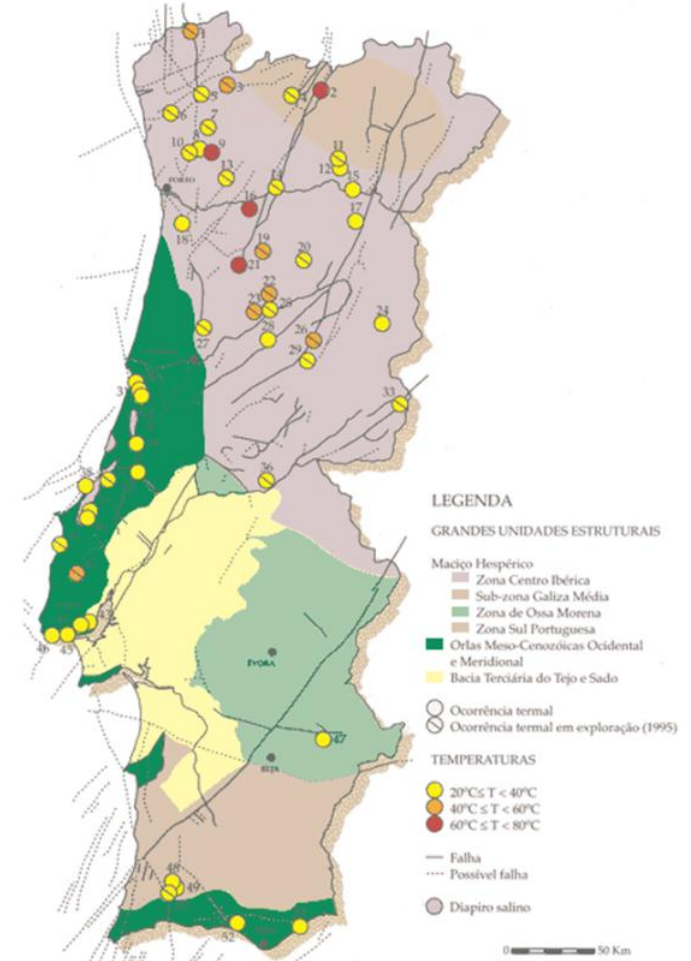
Total area	6 000 m ²
Core/cuttings storage capacity	200 000 m
Total km of core/cuttings stored	240



Available Data



GPEP oil survey wells, onshore & offshore

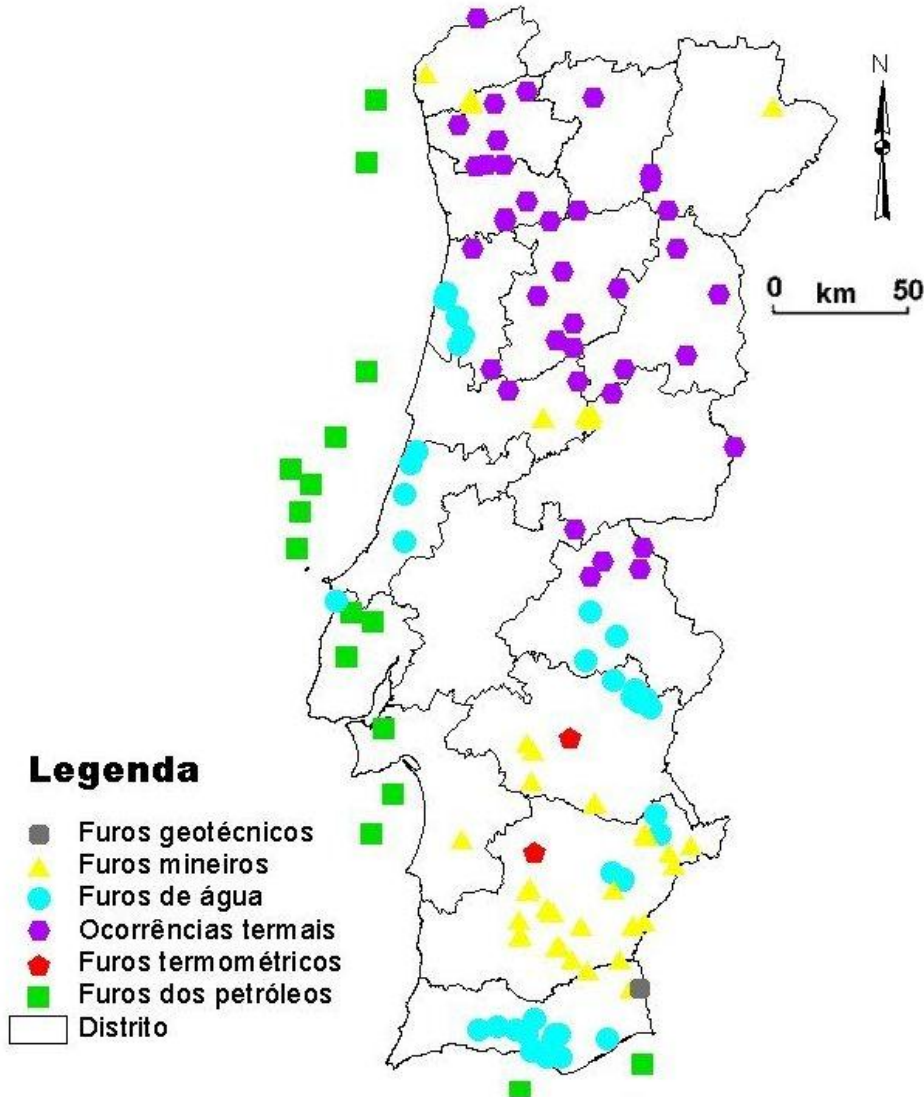


Thermal occurrences

Available Data

Thermometric measurements

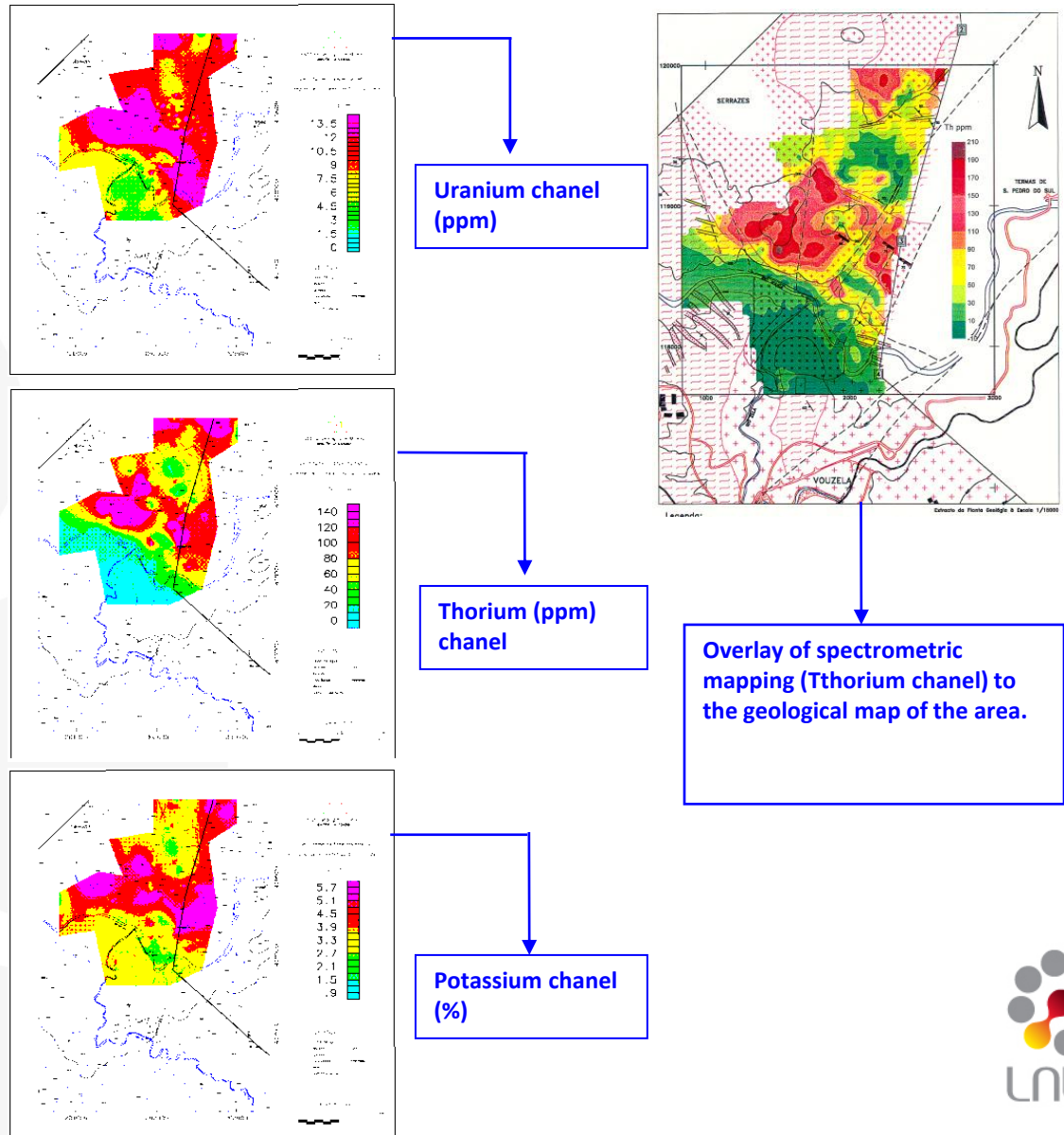
1982-2008



- Mine holes (deep, abandoned and well known);
- boreholes (large quantity, but with little knowledge of the lithology);
- thermometric holes (very scarce);
- oil wells;
- Geothermometers.

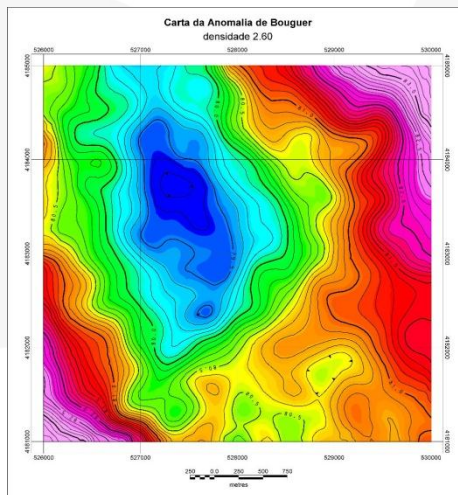
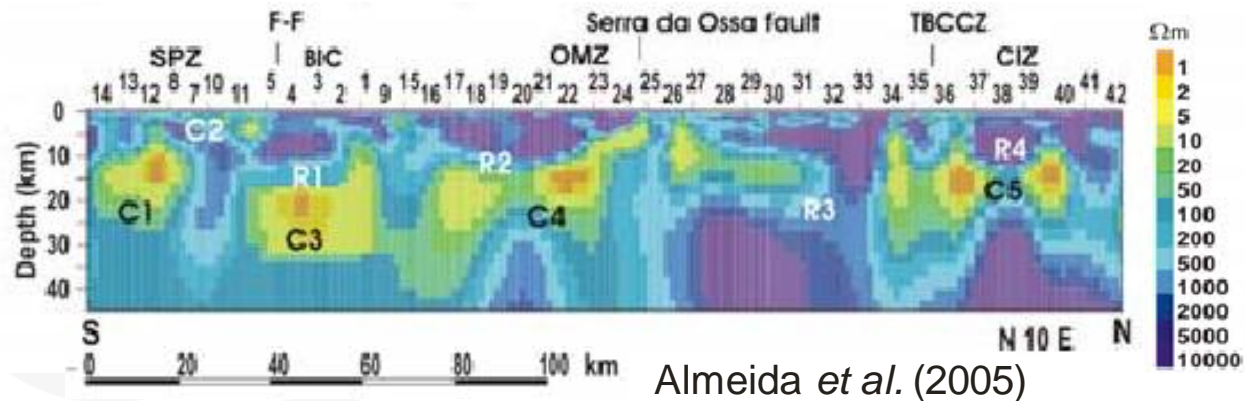
Available Data

Local spectrometric surveys of U, Th and K, which may be used in estimates of heat production of rocks (A).



Available Data

- The use of magnetotelluric prospecting allows investigation of great depths, it is also necessary in both enhanced geothermal projects and geothermal classic

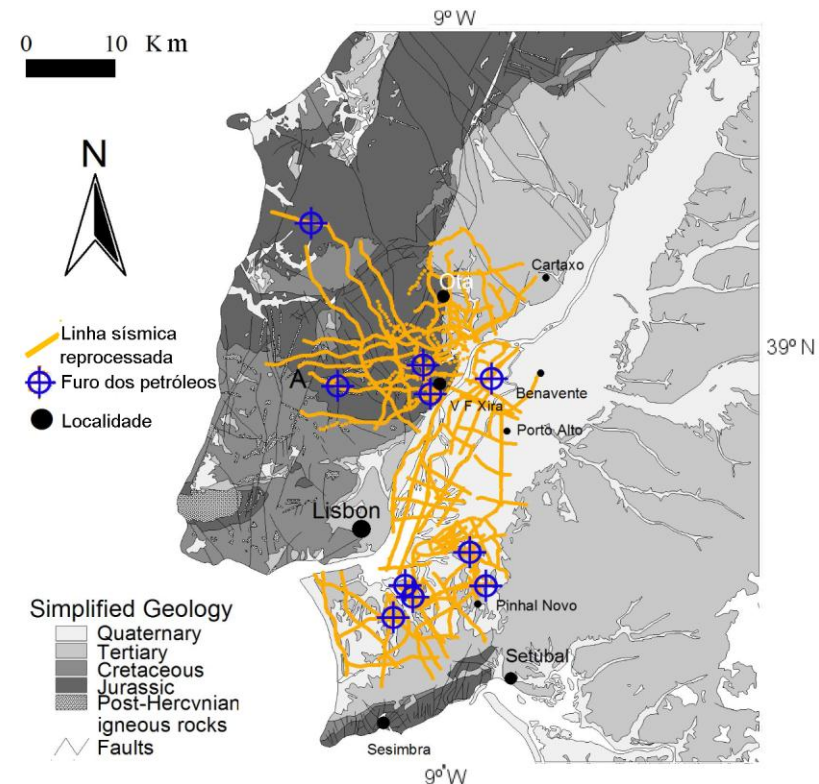


- Gravimetric and 2D and 3D gravimetric modeling which are important tools to know regional and even local geothermal features.

Available Data

Reprocessed seismic lines – LVT

- Reprocessing of seismic lines from Lisbon and Tagus Valley project FCT Sismotecto (GIS database on the Sismotectonics in Portugal).
- Data with great interest in the general knowledge of the thermal regime of sedimentary basins and in understanding of how it behaves locally



Geothermal Research - Ongoing activities

- The geothermal database and catalogue of the Portuguese territory (LNEG and DGEG).

LNEG
Laboratório Nacional de Energia e Geologia, I.P.

e-Ge

Catálogo de Recursos Geotérmicos em Portugal Continental

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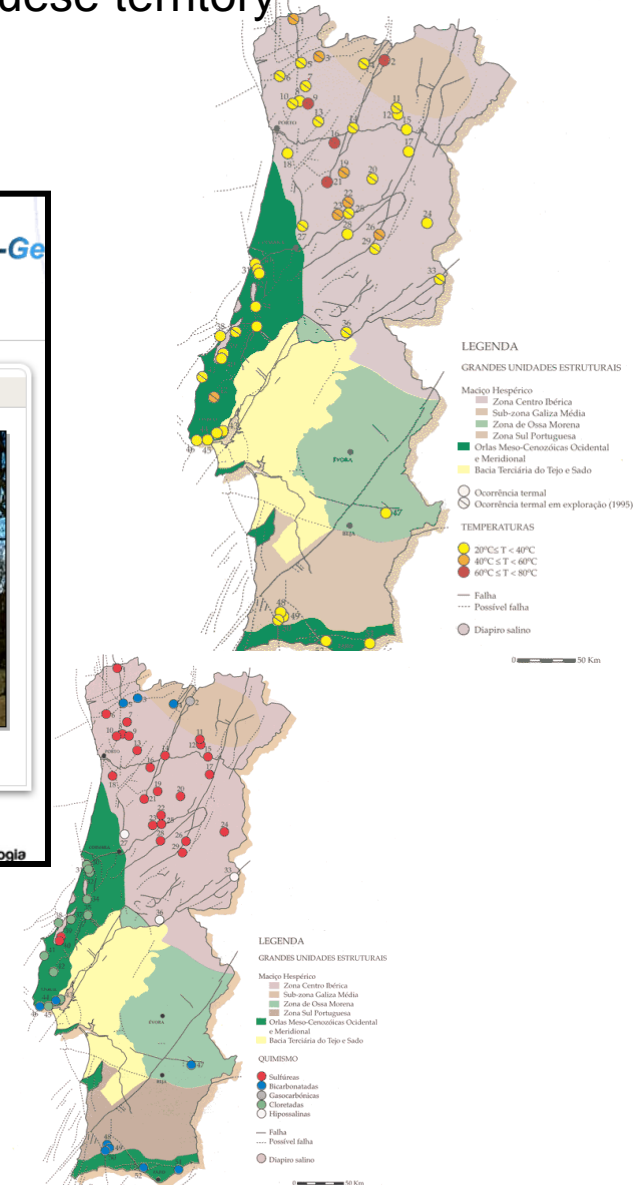
- ⇒ Apresentação e Autorias
- ⇒ Introdução
- ⇒ Legislação Aplicável
- ⇒ Localização e Modos de Ocorrência
- ⇒ Quimismo das Ocorrências
- ⇒ Aproveitamentos Geotérmicos
- ⇒ Utilização de Recursos de Baixa Entalpia (usos directos)
- ⇒ Pesquisa de Ocorrências Geotérmicas
- ⇒ Bibliografia Adicional



[Aceder à Base de Dados](#)

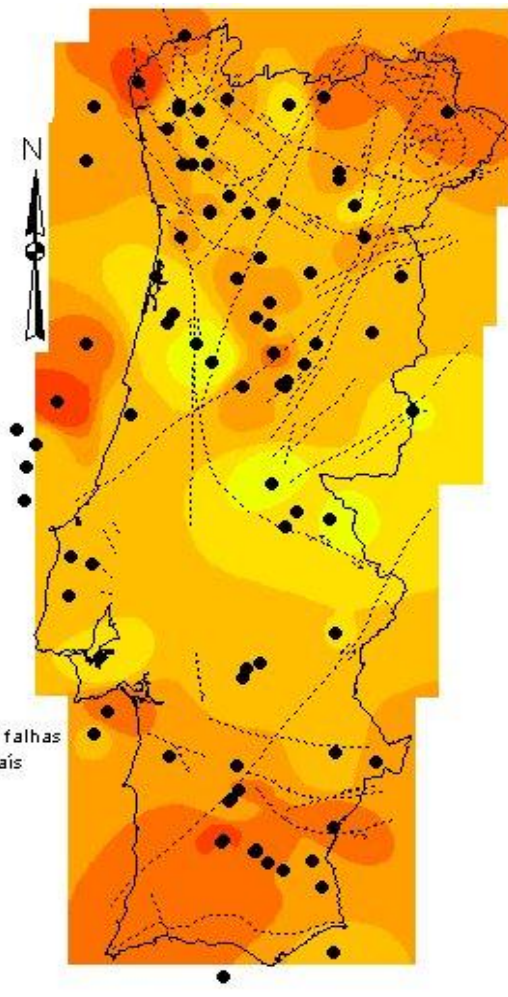
INETI

Direcção Geral de Energia e Geologia



Geothermal Research - Ongoing activities

Heat Flow Density at Surface mapping



- geothermal gradient (down hole temperature measurements)
- thermal conductivity
- radiometry
- U, Th and K spectrometry
- satellite images

Heat Flow Density at surface (HFD)

Heat production (A)

➤ Requires a considerable amount of field and office work.

Updated Surface Heat Flow Density Map in Mainland Portugal

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the magnification of the entire page



Tectonophysics 191 (1998) 29–33

TECTONOPHYSICS

Heat flow, heat production, and lithospheric thermal regime in the Iberian Peninsula

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Received 17 July 1997

Abstract

The first heat-flow and heat-production maps of the Iberian Peninsula and its margins using previously acquired data are presented. The surface heat-flow map includes 555 determinations carried out on water and mining exploration wells, oil exploration wells and on the seafloor. The surface heat flow varies noticeably from the Iberian mainland (65–10 mW m⁻²) to the Atlantic and the Mediterranean margins, where the heat flow reaches values of about 40–50 mW m⁻² and 80–100 mW m⁻², respectively. The heat-production map consists of 664 determinations carried out on rock samples from the Variscan Iberian Massif and the Betics. The higher values are obtained for granitic rocks (2.5–3.5 μW m⁻³), whereas metasediments and basic rocks reach values of 1–2.5 μW m⁻³ and nearly zero, respectively. The lithospheric structure deduced for the Iberian Peninsula by combining heat-flow, heat-production and elevation data indicates that most of the Iberian mainland is characterized by a lithospheric thickness of 110 ± 5 km. This value is maintained across the West Atlantic margin, whereas towards the Mediterranean margin, the lithospheric thickness decreases down to 60–40 km. This study also suggests that the heat production in the southern Variscan Iberian Massif must be noticeably higher (1.7–0.5 μW m⁻³) than in the rest of the area in order to fit the measured heat-flow, crustal thickness and elevation data. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: heat flow; heat production; thermal conductivity; lithospheric thickness; elevation; Iberia

1. Introduction

Worldwide heat-flow measurements show that the mean surface heat flow in continental areas is 57 mW m⁻² whereas in oceans it is 66 mW m⁻² (Sclater et al., 1980). On average, continental surface heat flow is split up into a radiogenic (crustal) component which reaches 40%, and a background (subcrustal) component which reaches 60% (Pollack and Chapman, 1977). These regional averages can be largely modified by tectono-thermal events (Chapman and Furlong, 1977; Vitellio and Pollack, 1980) or by shorter-scale processes such as groundwater flow and magmatic activity.

The Iberian Peninsula, located at the western-most edge of the Eurasian plate, has, since the lower Palaeozoic, undergone different tectono-thermal episodes which include the Variscan and Alpine compressions followed by the Mesozoic and Neogene extensions, respectively. As a result, the present-day Iberian Peninsula is characterized by dif-

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Surface Heat Flow Density map

geothermal information to draw a map and determine the geothermal potential. Portugal begins at the end of the Variscan orogenic cycle. The Variscan orogenic cycle has been working in the Iberian Peninsula since the late Palaeozoic and has also been operating in the crustal geothermal modeling and

large granitic regions in northern to several directions, surface heat flow data are difficult to obtain. Wells drilled there are shallower than those of the Portuguese mainland but regions. On the other hand, in Portugal, heat created a large and the region. In most Portuguese areas, data come from deep oil

information collected on the Iberian Peninsula. This study was considered the first heat flow density map of the Iberian Peninsula. It is the first time that a heat flow density map is compared with a map of the Iberian Peninsula. It is the first time that a heat flow density map is compared with a map of the Iberian Peninsula. It is the first time that a heat flow density map is compared with a map of the Iberian Peninsula.

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1. Introduction

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throughout the country, with temperatures ranging from 10 °C to 70 °C in shallow boreholes. The most important one, with high temperatures and hydrothermal characteristics, is located in the northern part of the country, in the so-called Guadalupe Zone (GZ). Geotectonic units of the Iberian Massif (Fig. 1). Most of these emerge in crystalline rocks with the water from the GZ. Local and regional fluid systems. Chemical characteristics of the water vary from plain to phreatic (Fig. 2). In an average, low mineralized sulphates and bicarbonates water is common in the Iberian Massif, while high mineralized waters, chloride and sodium rich, occur in the Mesozoic Basin (Correia et al., 1996).

2. GEOLOGICAL SETTING

Mainland Portugal has a remarkable geological heterogeneity with formations ranging from the Precambrian to the Quaternary (Fig. 2). This variety leads to the existence of several geothermal zones, which depend on the geology and local and regional structural features.

Mainland Portugal is divided into three major tectonic



Tectonophysics 291 (1998) 55–62

New heat flow density data from southern Portugal: a geothermal anomaly revisited

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Received 11 August 1997

Abstract

Previous geothermal work has indicated that a geothermal anomaly with heat flow density values in excess of 200 mW/m² exists in southern Portugal. Other geological and geophysical data from the area show no evidence of such an anomaly. To determine whether or not a geothermal anomaly occurs there, the published geothermal data and some new temperature data obtained from newly available wells, as well as from some of the previously used wells, were reprocessed. The reprocessing of the published data took into consideration thermal and hydrodynamic equilibrium criteria, and so some of the wells that were previously used to draw the heat flow density map were rejected. Reprocessing of the data, together with the new measurements, indicate that a geothermal anomaly does not exist in the area and that it is a normal feature of the Hercynian region in Europe. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: heat flow density; geothermics; Portugal

1. Introduction

The first surface heat flow density (HFD) estimates made for Mainland Portugal were for the Alentejo region and were published in 1982 (Correia et al., 1982). These estimates were calculated using geothermal information from several mining wells. The information consisted of measured temperature profiles and thermal conductivities of rock samples from the standard wells measured in the laboratory. As a continuation of this early work, further HFD determinations were made and, in 1988, a first HFD

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One-dimensional thermal models constrained by seismic velocities and surface radiogenic heat production for two main geotectonic units in southern Portugal

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Received 8 February 1998; accepted 24 November 1998

Abstract

New heat flow density data and radiogenic heat production values obtained in southern Portugal, along with lithologic and structural data inferred from vertical seismic velocity distributions from deep seismic reflection surveys, are used to construct one-dimensional (1D) geotherms for the crust in the two main geotectonic units of the region, i.e. the Ossa-Morena Zone (OMZ) and the South Portuguese Zone (SPZ). Surface radiogenic heat production values calculated using potassium, uranium and thorium concentrations measured in different rock types were used to constrain the best production values. In the Ossa-Morena Zone and South Portuguese Zone the surface radiogenic heat production does not exceed 1.5 μW m⁻³. A geotherm was constructed assuming that the crust in the region is a two-layer structure. Backcasts in the OMZ and SPZ. For both zones two 1D geotherms. The models suggest that temperatures are higher of about 300°C at Moho depths; however, best production so temperatures in the SPZ are probably overestimated. For the results were correct best production is assumed for the crust. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: heat flow density; geotherms; Ossa-Morena Zone; South Portuguese Zone

TECTONOPHYSICS

low the construction of thermal models for the region. Southern Portugal is geologically complex but comprises one of the best exposures of the Hercynian orogeny in Europe. There is now enough geothermal information to start to construct geothermal models which may give more insight into the geodynamic behaviour of the orogen in Portugal. As a first attempt to model the geothermal regime in southern Portugal, one-dimensional geothermal models are constructed

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RECURSOS GEOTÉRMICOS DE BAIXA ENTALPIA EM PORTUGAL CONTINENTAL

Maria Carla LOURENÇO**

RESUMO

Segundo Portugal um país importador de energia, torna-se essencial aproveitar todo o seu potencial, nomeadamente as energias renováveis, dentro das quais se enquadram os recursos geotérmicos.

Os recursos geotérmicos foram inicialmente definidos e regulamentados em 1976, com o objetivo de suportar legalmente o projeto geotérmico dos Açores. O novo pacto legislativo de 1990 (Decreto-Lei n.º 50/90 e Decreto-Lei n.º 87/90) veio dar uma nova dimensão ao sector, permitindo uma gestão adequada dos recursos geotérmicos por parte da Administração.

No topo são poços secos águas com temperaturas elevadas, que variam entre os 20°C e os 70°C, pelo que se torna importante a realização do conhecimento sobre tipo de águas.

Com vista a adquirir um conhecimento mais aprofundado relativamente aos recursos geotérmicos, encontra-se em curso um projeto de investigação e avaliação das condições no território de Portugal Continental, cuja equiparação de energia seja superior a 20°C. Este projeto é liderado a cabo pelo Instituto Geológico e Mineiro.

Palavras-chave: geotermia, baixa entalpia, ocorrência térmica

APROVEITAMENTOS GEOTÉRMICOS EM PORTUGAL CONTINENTAL

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Resumo

No que se refere ao aproveitamento das chamadas "águas entalpias", a energia geotérmica é já bem conhecida por algumas realizações que permitem a produção de energia elétrica. Exemplo típico no nosso país é o que se passa no Arquipélago dos Açores, na ilha de S. Miguel, onde há já vários anos se encontra a funcionar uma central geotérmica.

Em Portugal Continental, o panorama é já um pouco diferente. Saí-se do domínio das chamadas "águas entalpias" para se entrar no domínio das "baixas entalpias". Mas mesmo neste domínio, com fluxos e temperaturas moderadas (até cerca de 100°C), se podem efectuar aplicações a nível da indústria, aquecimento urbano e agricultura.

Em virtude de uma complexa e diversificada geologia, Portugal Continental possui um aprofundado potencial geotérmico, evidenciado pela elevada número de ocorrências com temperaturas superiores a 20°C, verificadas com finalidades termais desde tempos antigos. Nos últimos anos tem-se vindo a observar um interesse crescente na realização de estudos e projetos que têm em vista o aproveitamento da energia geotérmica, nomeadamente o equipamento dos próprios estabelecimentos termais, de unidades turísticas, de piscinas e de estufas agrícolas. Alguns dos projectos encontram-se actualmente em funcionamento.

O potencial geotérmico em Portugal Continental pode ser aproveitado por duas vias: (i) o aproveitamento dos recursos da rede central de águas termais existentes com temperaturas entre 20 e 70°C e; (ii) do aproveitamento de aquíferos profundos nos orlões Mesozoicos Ocidentais e Meridionais, revelados pelos furos de reconhecimento petrolíferos. No primeiro caso temos em funcionamento, desde o meado dos anos 80, aproveitamentos geotérmicos em Chaves e S. Pedro do Sul. Outros poços inexplorados, com grande disponibilidade do recurso e marcado interesse em Angola, Visão, e Hongo. No caso das Bacias Sedimentares Pré-Alébricas, no Hospital da Torre Alena no Lurio, em Lisboa, uma operação geotérmica em furo único (com 1500 m de profundidade e 50°C à cabeça do mesmo), destinada à produção de água quente sanitária, distinguindo-se a água quente fria. Para a obtenção da água quente a 100°C a 475 metros de profundidade (30°C à cabeça do poço), nos Serviços Sociais das Forças Armadas (Oeiras), ainda que neste caso seja aplicado com finalidades de calor.

No presente comunicação relatamos os principais resultados obtidos até ao presente e identificamos os princípios orientadores do desenvolvimento compreensível. De igual modo, faz-se uma referência ao enquadramento legislativo no aproveitamento dos recursos geotérmicos e conclui-se com um enunciado de propostas orientadas para a avaliação e melhor aproveitamento dos recursos geotérmicos nacionais.

Palavras-chave: geotermia, baixa entalpia, ocorrência térmica



Instituto Nacional de Engenharia, Tecnologia e Inovação

CONTRIBUTO PARA A CARACTERIZAÇÃO TÉRMICA DA CROSTA EM PORTUGAL CONTINENTAL

Análise e processamento de dados geotérmicos compilados até 1996

Elsa Ramalho (INETI)
António Correia (U.E./C.G.E.)

Maio de 2006

CORREIA, A., RAMALHO, E., RODRIGUES DA SILVA, A. M., MENDES-VICTOR, L. M., DUQUE, M. R., B. AIRES-BARROS, L., SANTOS, F.M. and AUMENTO, F. (2002) – Portugal – In: Atlas of Geothermal Resources in Europe (Eds: Suzanne Hurter and Ralph Haenel), GGA, Hannover, Germany. 92p., 89 plates. pp.47-49. ISBN92-828-0999-4.

Geothermal Research - Ongoing activities

EGEC- Contribution towards the Strategic Agenda and other documents

GEOFAR - Geothermal Finance and Awareness in European Regions

GeotherMadeira - Evaluation of the geothermal potential of Madeira Island (LNEG; Uni. Lisbon; Uni. Évora).



Geothermal Research - Ongoing activities

Madeira Island

Active volcanism (but no historical eruptions)

Evaluation of geothermal potential by a consortium led by LNEG, in a partnership with the Electricity Enterprise of Madeira (EEM).

Methodology:

- Identify and characterize the recent volcanism
- Structural geology and evaluation of stress fields
- Temperature measurement in wells and tunnels
- Geothermometers applied to water
- Gravimetric, magnetometric and seismic tomography



Geothermal Research - What is missing

Submitted projects:

AQUATERM

Sources and pathways for hot water: A contribution for geothermal development

District heating in the Lisbon area

IBERTHER – Evaluation of the geothermal potential of the Iberian Peninsula
(LNEG; LNEC; Uni. Lisbon; Uni. Évora; IGME; Uni Barcelona)

Geothermal Research - What is missing

- Increase the knowledge base to attract investment:

Restrict the favorable areas for deep geothermal energy

Gather geo-information into GIS and 3D models:

geothermal gradients,
depth and type of basement,
stress regimes,

- Bring a demonstration / pre-commercial plant to Portugal (mainland and/or volcanic islands).

Triggers:

- ✓ EU funding (EERP, etc);
- ✓ Favorable feed-in tariffs.

Needs:

- ✓ Partners with innovative technological approaches to reservoir characterization+stimulation and/or electricity generation.

Thank You!



Geothermal Research

Ongoing activities

-Mainly focused on direct uses from thermal springs. Technical support (geological and geophysical surveys) was given to license holders.



Geothermal well at S. Pedro do Sul



Geothermal well at Moledo