National Laboratory for Energy and Geology
www.lneg.pt

Laboratory of Energy

Laboratory of Geology and Mines

Geothermal Resources in Portugal

EGEC GEOELEC Workshop

Nov 10th, 2011 - Valencia

Geothermal Resources in Portugal

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

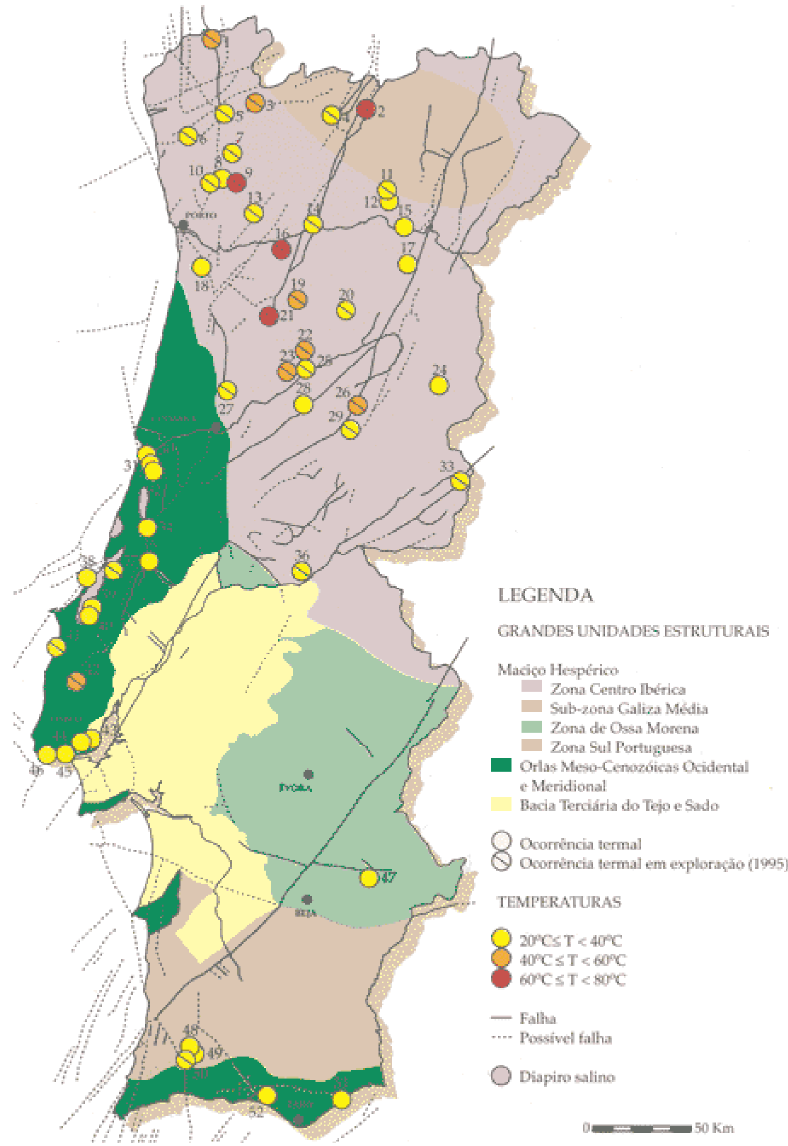
Geothermal Potential (Mainland)

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.

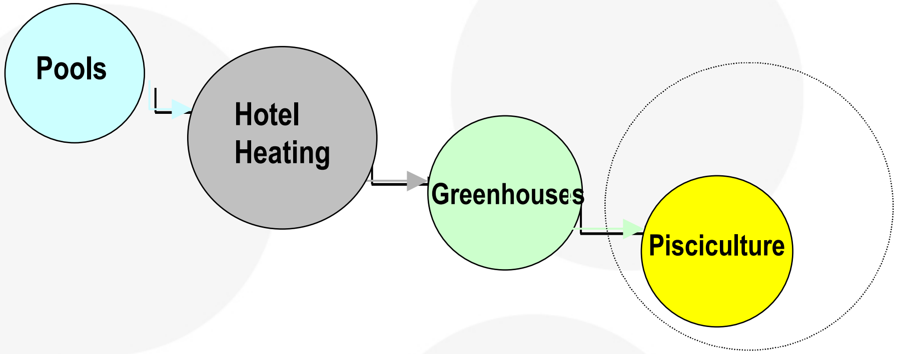
- The geological characteristics of the country enhance the existence of other low enthalpy geothermal exploitable places.



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 76º 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 (63º 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:
  - 30º C in natural occurrences (Lisbon and Vila Franca de Xira);
  - 50º C in cores of 1500 m depth (Lisbon,Lumiar);
  - 56º C, in cores of 300 depth in a diapiric area (Torres Vedras)

LNEG

Geothermal Potential (Azores)

Active volcanic area

S. Miguel Island (5

- Ribeira G
- Pico Ver

W)

Pico Vermelho geothermal

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

Terceira Islar

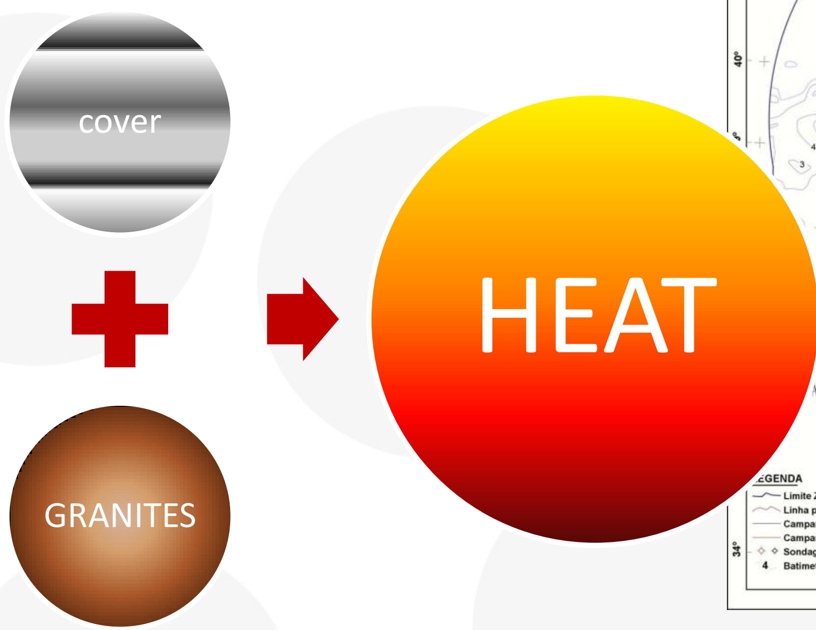
Res

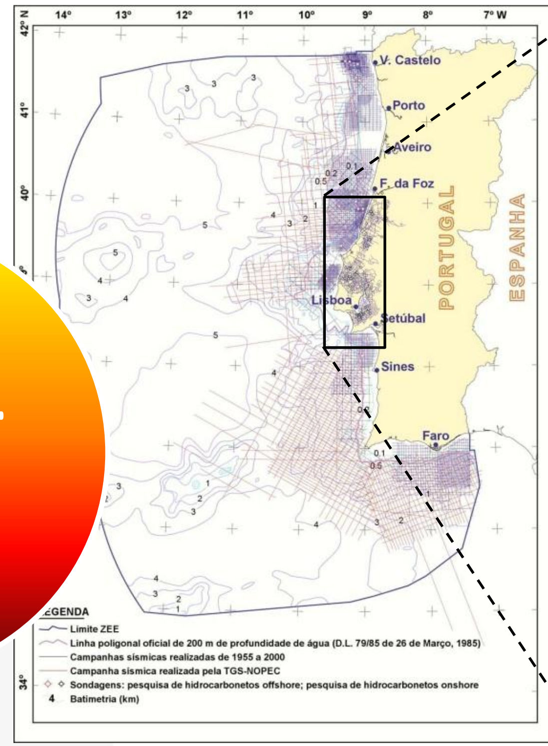
Low

Pilot powerplant of 3 MW

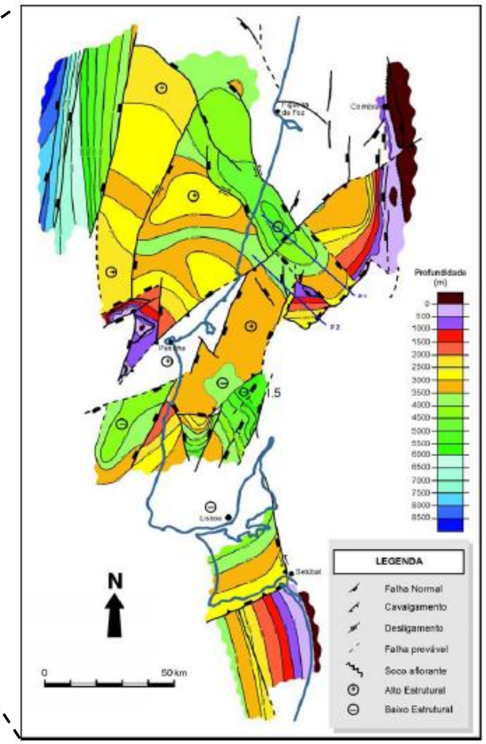
Geothermal Potential (Mainland)

High Enthalpy - EGS





Dir.Geral Energia Geologia



Kullberg et al (2006)

- Favorable geology to develop EGS :
  - Radioactive Granites
  - Sedimentary Basins

Positive (?) political/institutional framework

LNEG

Geothermal Potential
High Enthalpy - EGS

Promising areas (**Mainland**):

Trás-os-Montes

Douro

Pinhal

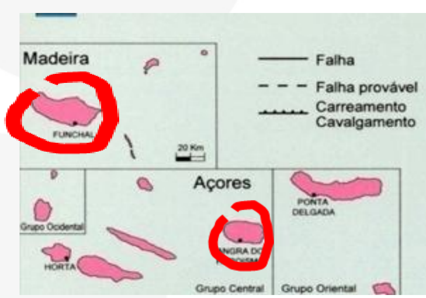
MC Basin

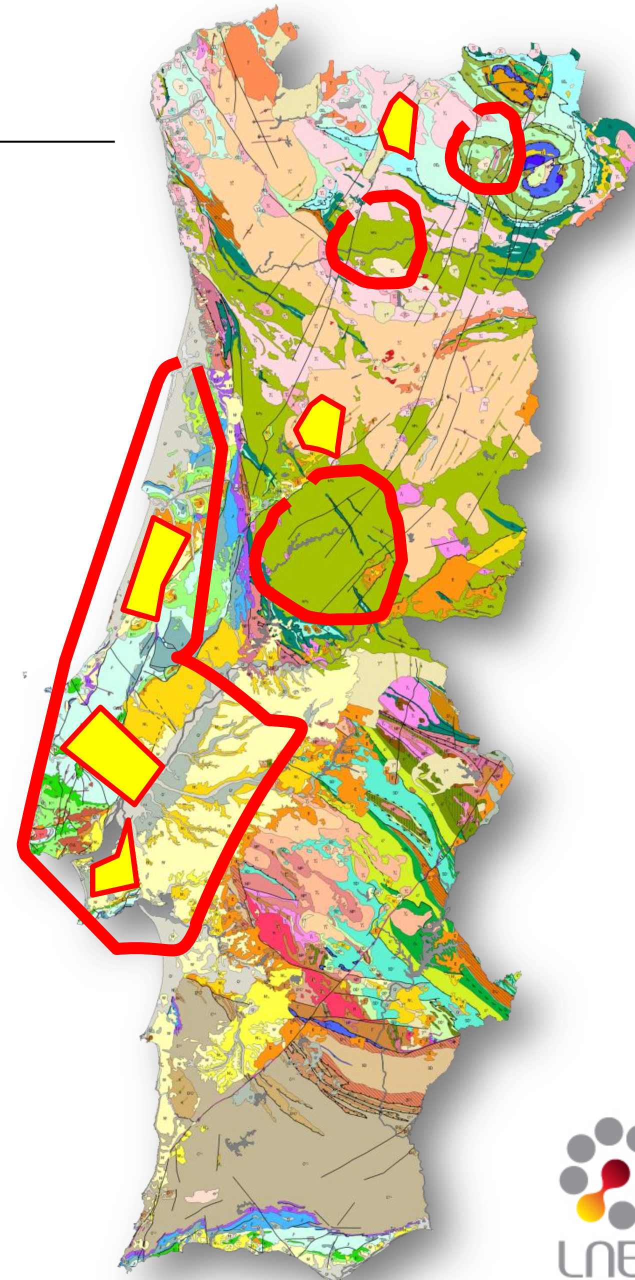
- 5 permits to private enterprises

Islands

Azores

Madeira





LNEG

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).

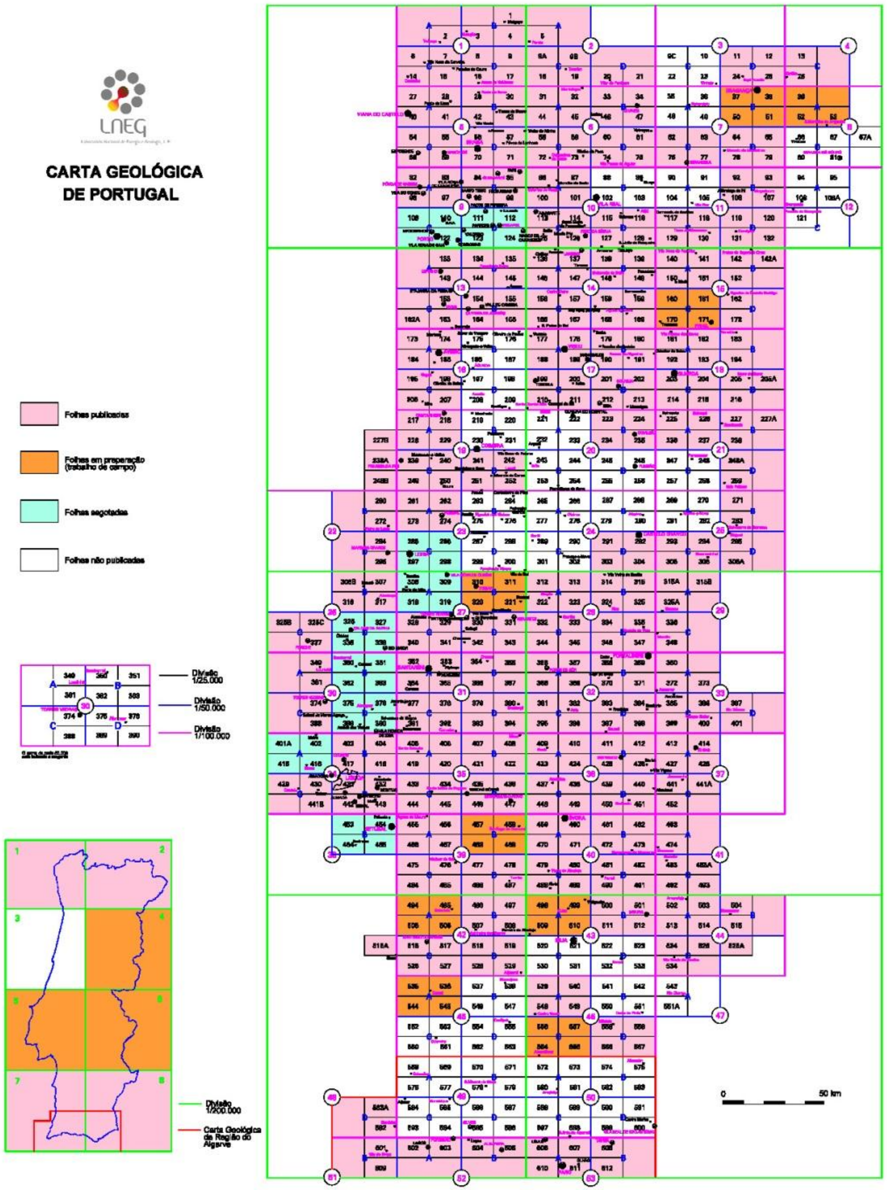
Available Data

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

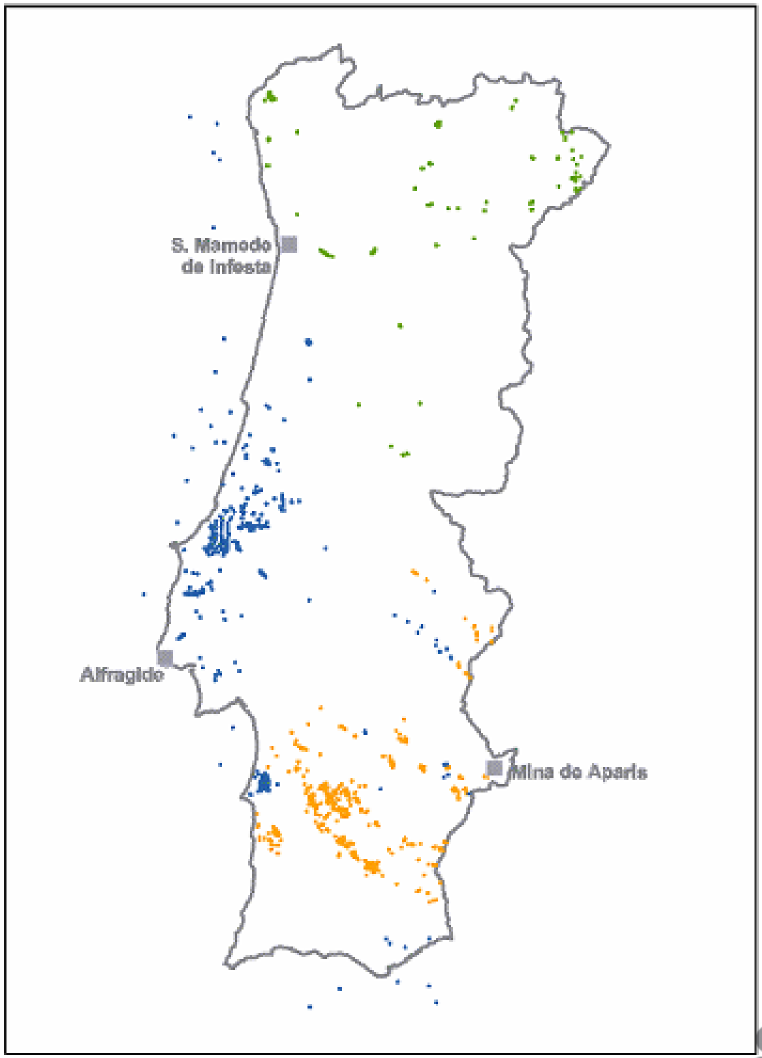
Drill Core @ Sample Storage @ LNEG

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

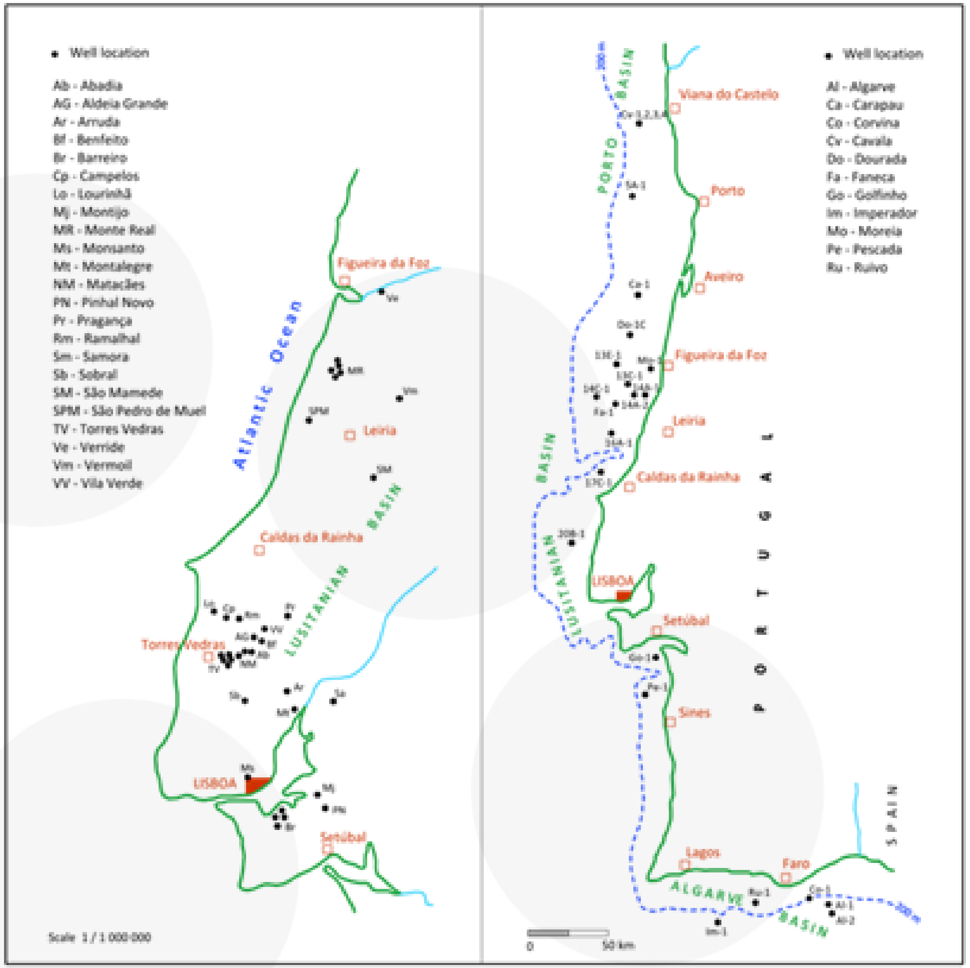
Total area	1 200 m^2
Core/cuttings storage capacity	200 000 m
Total of stored core/cuttings	730
Total km of core/cuttings stored	195

Barrancos - Alentejo

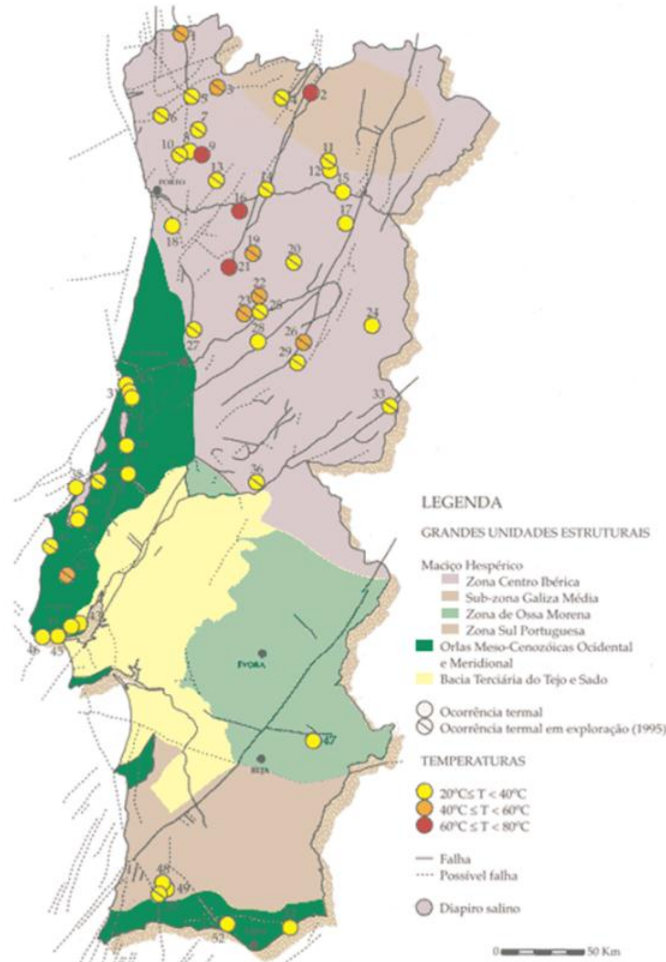
Total area	6 000 m^2
Core/cuttings storage capacity	200 000 m
Total km of core/cuttings stored	240

LNEG

Available Data



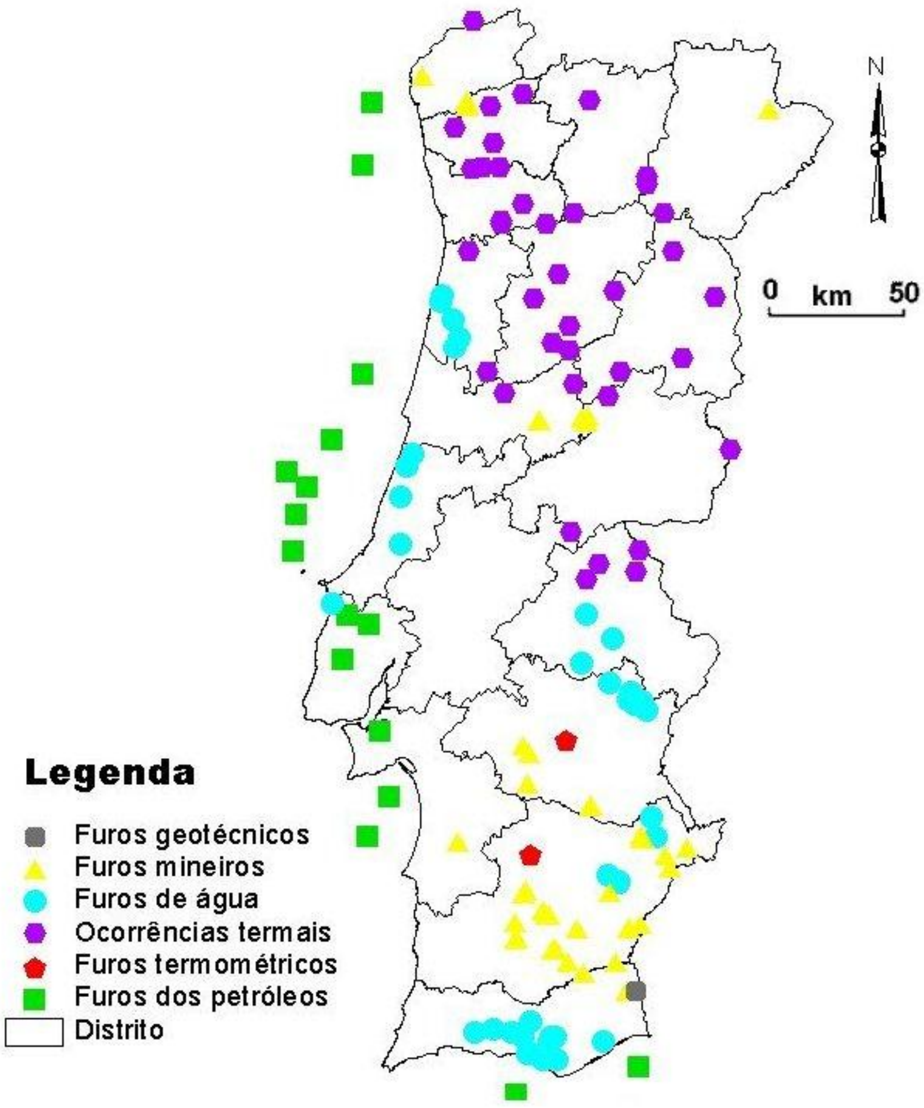
GPEP oil survey wells, onshore & offshore



Thermal occurrences

LNEG

Available Data



Thermometric mesurements

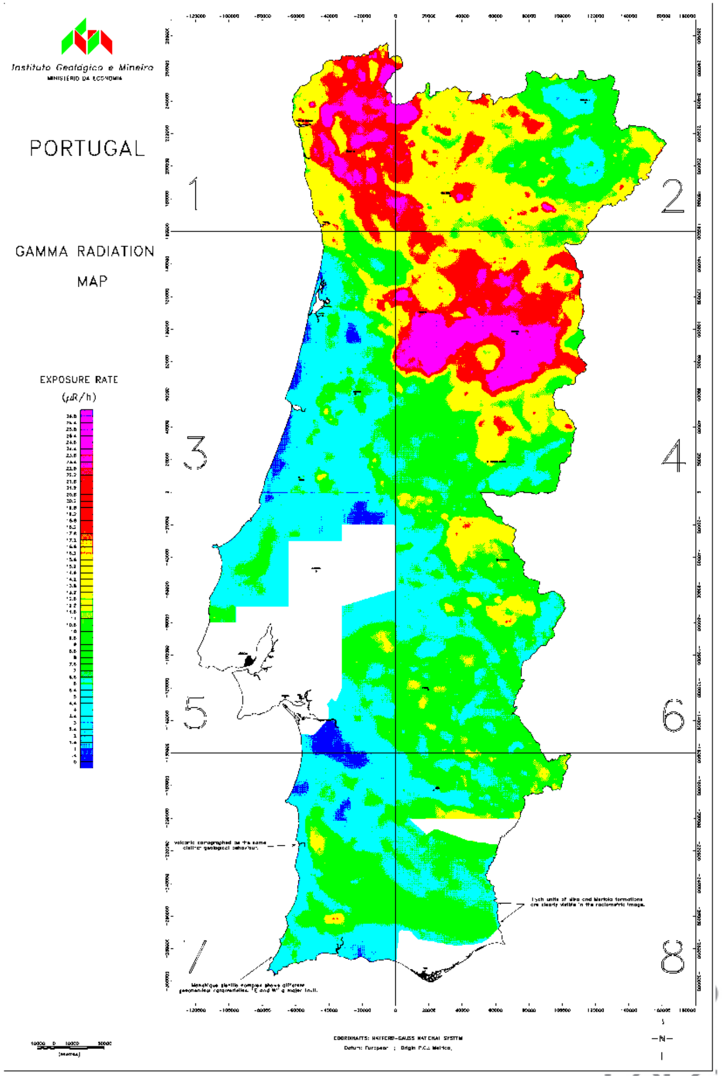
1982-2008

- 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

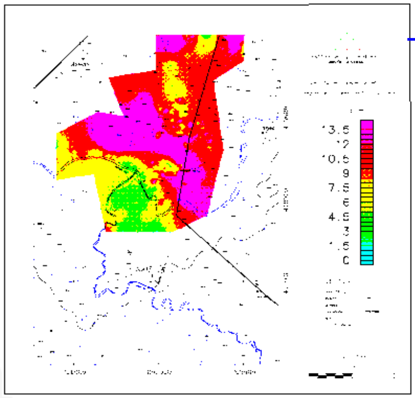
Radiometry

- Radiometric survey of mainland Portugal in its final stages. Sheet 5 in the finals.
- a significant amount of data are derived from spectrometric surveys, integrating the spectral windows of U, Th and K.

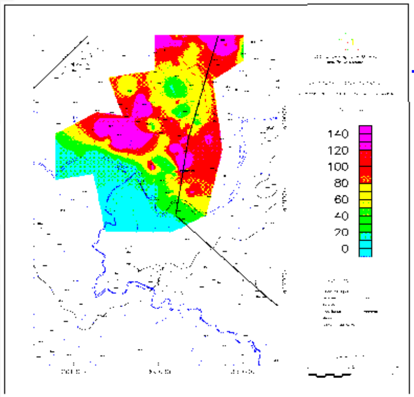


Available Data

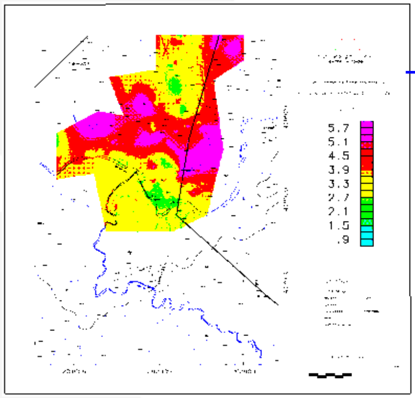
Local spectrometric surveys of U, Th and K, which may be used in estimates of heat production of rocks (A).



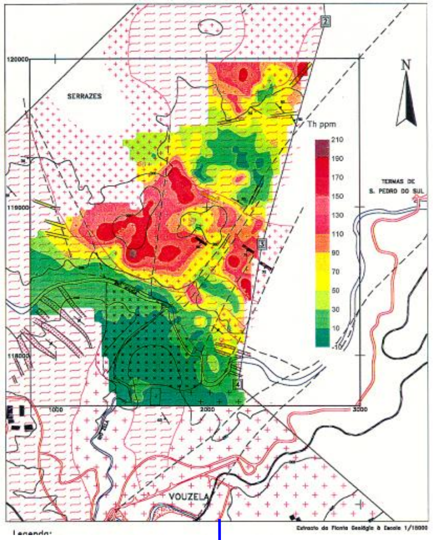
Uranium chanel (ppm)



Thorium (ppm) chanel



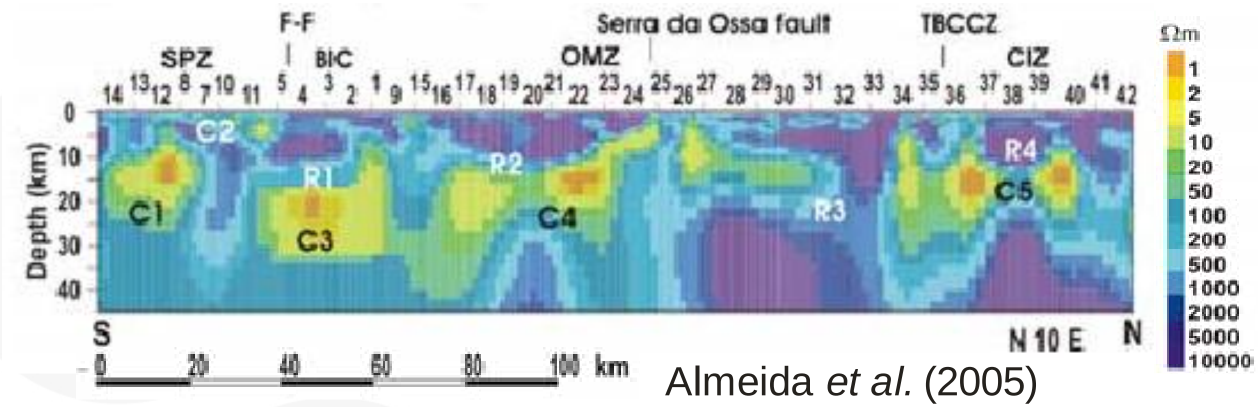
Potassium chanel (%)



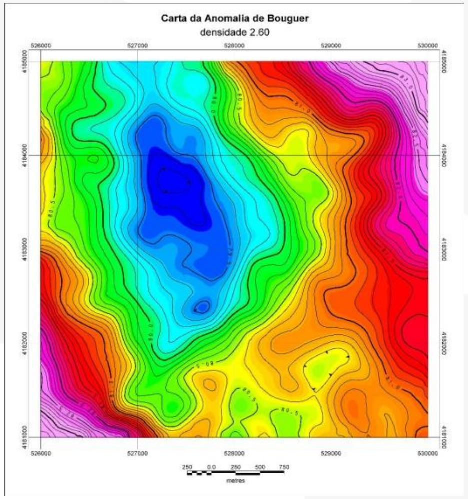
Overlay of spectrometric mapping (Tthorium chanel) to the geological map of the area.

Available Data

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



Almeida *et al.* (2005)



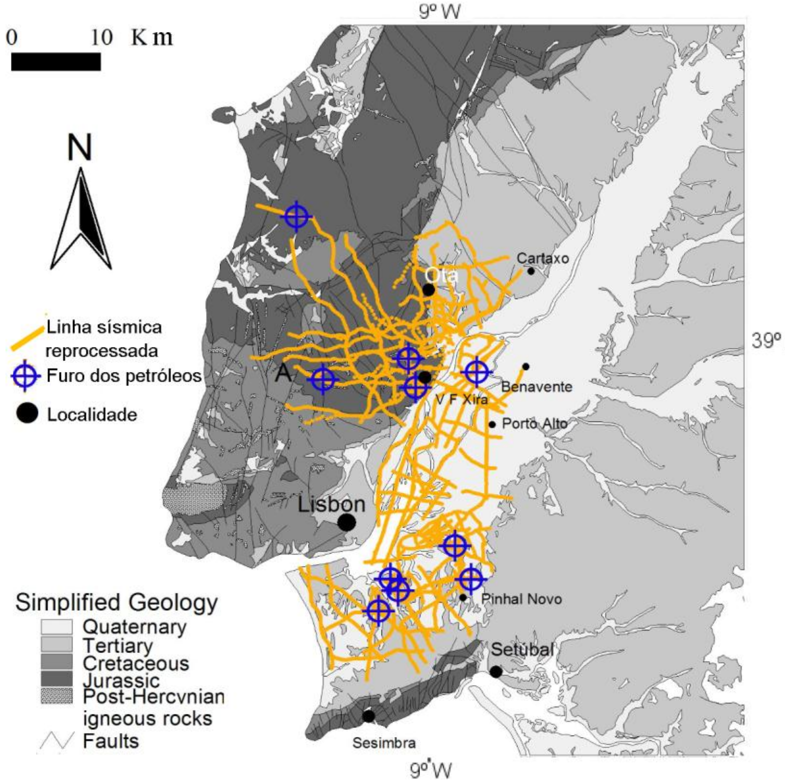
- Gravimetric and 2D and 3D gravimetric modeling which are important tools to know regional and even local geothermal features.

Available Data

Reprocessed seismic lines – LVT

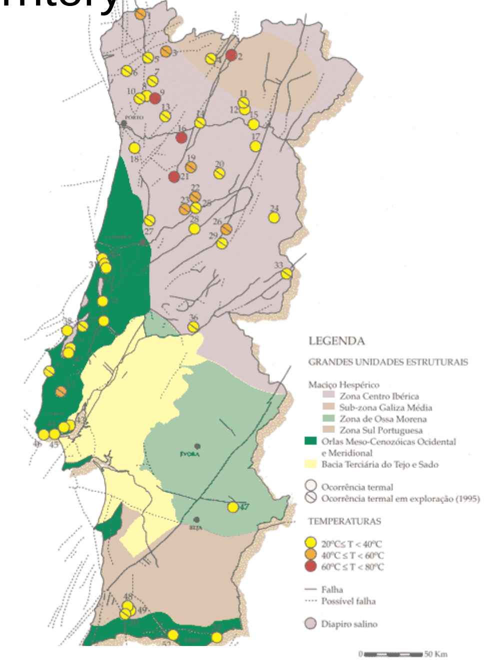
- Reprocessing of seismic lines from Lisbon and Tagus Valley project FCT Sismotecto (GIS database on the Sismotectonics in Portugal).

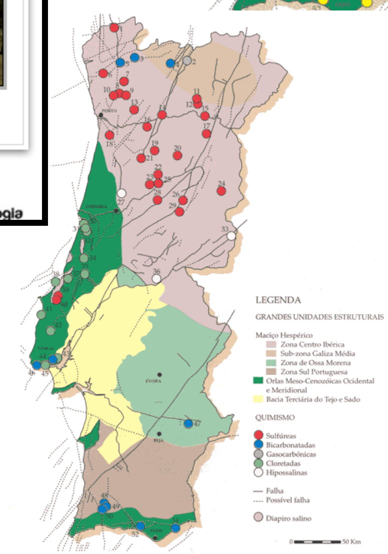
- Data with great interest in the general knowledge of the thermal regime of sedimentary basins and in understanding of how it is behaves locally



Geothermal Research - Ongoing activities

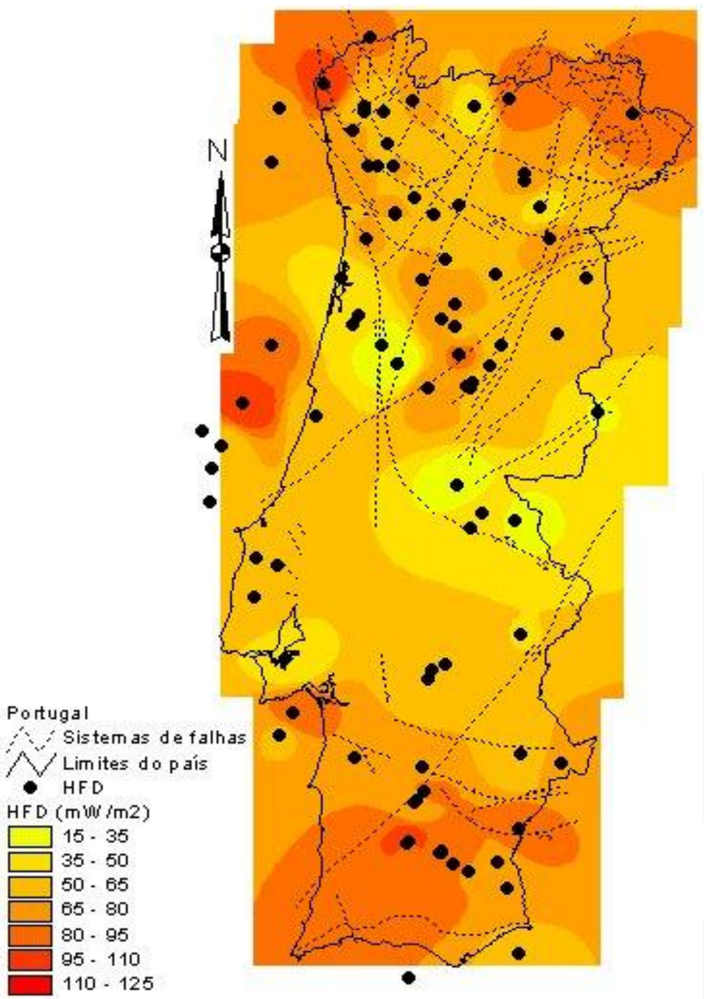
- The geothermal database and catalogue of the Portuguese territory (LNEG and DGEG).





Geothermal Research - Ongoing activities

Heat Flow Density at Surface mapping

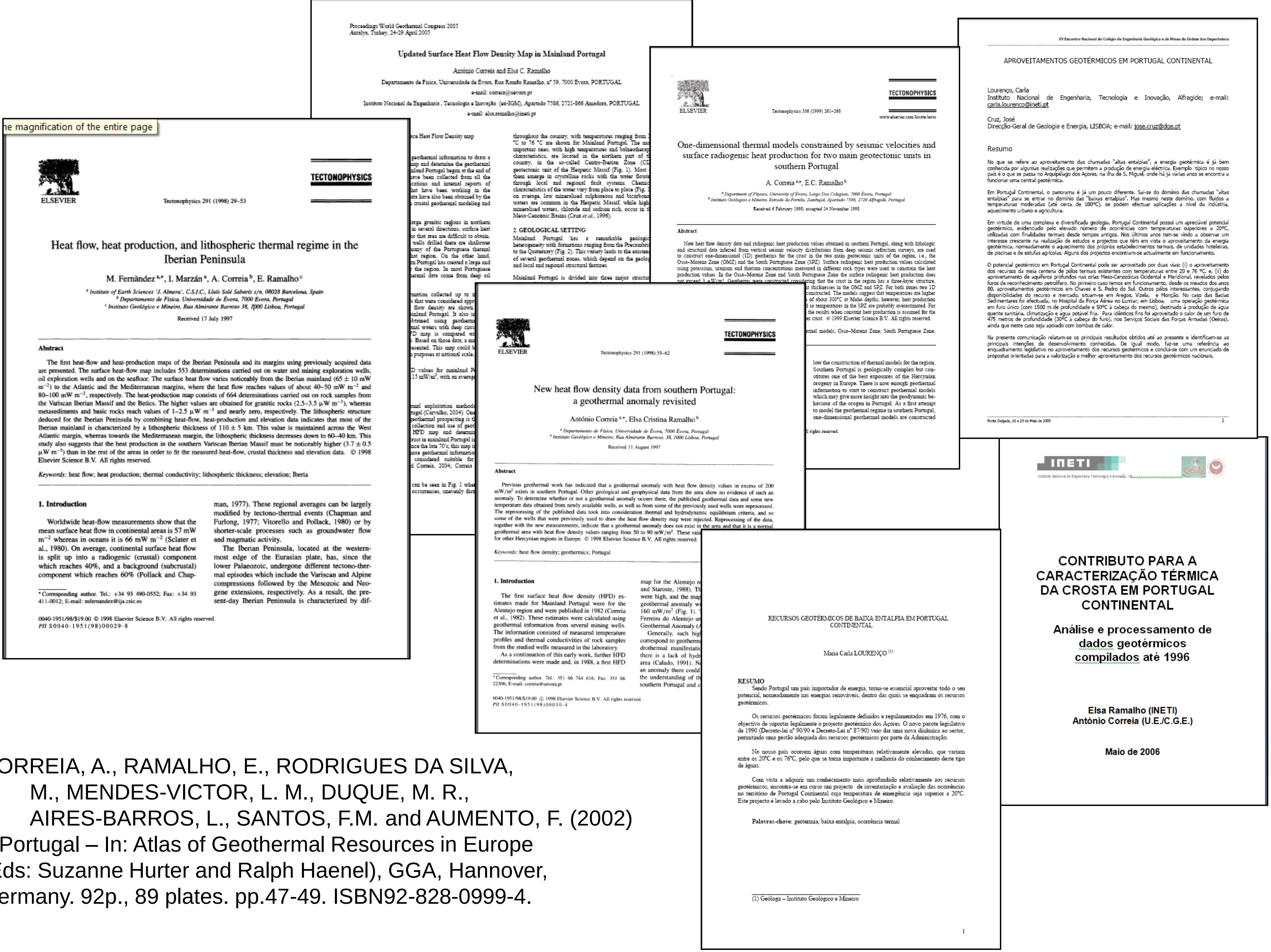


- geothermal gradient
  (down hole temperature measurements)
- thermal conductivity
- radiometry
- U, Th and K spectrometry
- satellite images

→ **Heat Flow Density at surface (HFD)**

→ **Heat production (A)**

➢ Requires a considerable amount of field and office work.



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

LNEG

Geothermal Research - What is missing

Submited 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.

LNEG

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