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HEAT FLOW IN THE SW OF GALICIA AND NW OF PORTUGAL. THE INTERPRETATION OF A SEISMIC ANOMALY

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Introduction

The principal aim of this work is to obtain information about heat flow density and temperature-depth values in a region without measured heat flow density values using different types of geophysical data obtained in the region for other purposes and available from the literature. Special attention is given to a region with seismic velocity anomalies explained as mass deficit due to an aquifer with hot water in the region. The region is located in Northwestern Portugal and Southwestern Galicia (Spain) in the Western part of the Iberian Peninsula between latitudes 41.55 ºN and 42.7 ºN and longitudes 7.9 ºW and 8.7 ºW. The main type of geological formations in the region is granitic rocks traversed by several faults and two hot springs are identified near latitude 42.2 (Model-A). Three different ages of granites with different contents of Uranium Thorium and Potassium were identified in the region in formations with different thicknesses. These results are complemented by radiometric charts presenting high values of exposure rates in the region. The heterogeneity of the region is shown on seismic models of the crust (vertical profiles and horizontal distributions at several depths) and in gravity data. Geoid height values over 56.0 m were obtained in the region except in model E where a value of 55.85 m was found.

Material and Methods

The method used is based on the assumption that the heat flow measured at the surface Q_o in a region without important tectonic thermal events includes the contribution of deep heat sources located in the mantle Q_M and heat sources located in the crust Q_C. Assuming a heat flow value from the mantle and knowing the value of the heat sources in the crust it is possible to find the heat flow at the surface. Five models were made in the region using crustal thickness values obtained on seismic profiles and heat production of 0.1 μW m^{-3} in the lower crust and 2.0 μW m^{-3} in the intermediate crust. No heat sources are considered in the upper mantle. Geotherms were obtained using the heat flow density values found and considering steady-state heat conduction in the vertical direction. Thermal conductivity values of 2.1 W m^{-1} K^{-1} and 2.5 W m^{-1} K^{-1} were used for the lower and upper crust respectively. A value of 15 ºC was used as temperature value in the upper boundary of the model. Five models were built to obtain the heat flow density and temperature-depth profiles in the region.

Results

The profile F-F´[4] (longitude 8.5ºW) was used in three different latitudes to make models A, B and E. The profile A-A´was used to make model D (longitude 8.0 ºW). Model C-Ourense was used to obtain the heat flow density value from the mantle to the base of the crust (35.1 mW m^{-2}). This value was used to obtain the heat flow values at the surface with the other models.

Models B and E are located at latitudes 41.6 ºN (model E) and 42.6 ºN (model B).They can give us the heat flow density in the region without the anomaly related to the aquifer (model A).

Model B and Model E

Depth (Km)	Thermal conductivity K (W $k^{-1}m^{-1}$)	Heat production A (μW m^{-3})	Depth (Km)	Thermal conductivity K (W $k^{-1}m^{-1}$)	Heat production A (μW m^{-3})
0-4	3.2	4.5	0-5	3.2	4
4-19	2.5	2	5-18	2.5	2
19-22	2.3	1.3	18-21	2.3	1.2
22-27	2.1	0.1	21-30	2.1	0.1

Model A

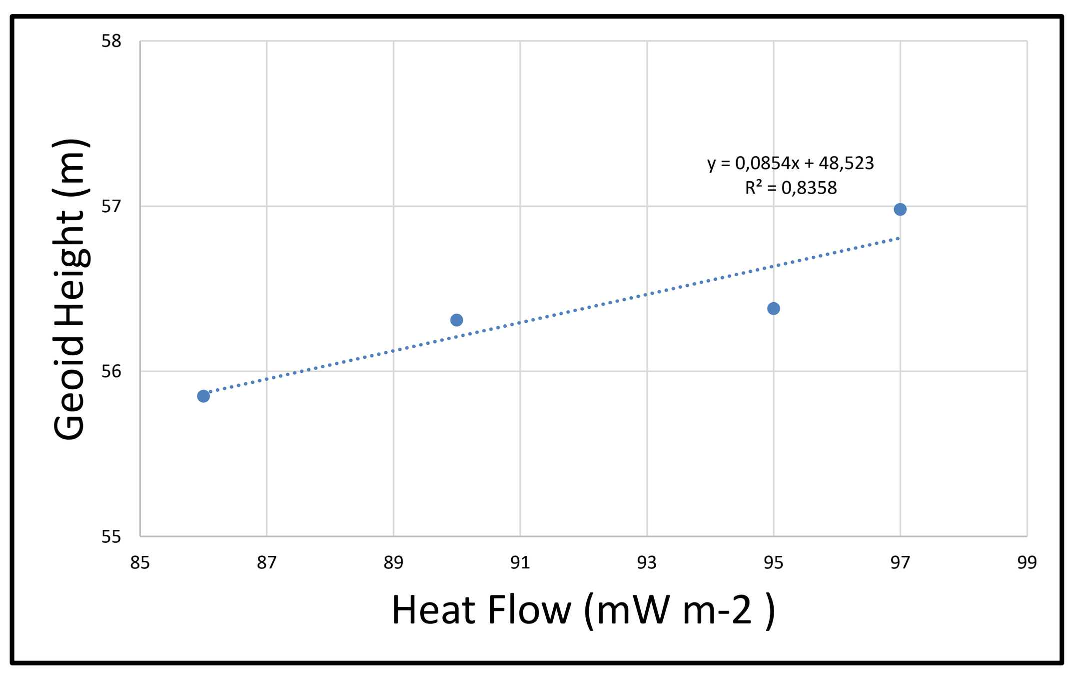
Depth (Km)	Thermal conductivity K (W $k^{-1}m^{-1}$)	Heat production by radioactive elements A (μW m^{-3})
0-2	2.76	3.6
2-4	3.0	4
4-6	3.17	4.3
6-7	3.3	4.5
7-10	2.5	2
10-14	2.4	2
14-20	2.3	1.25
20-28	2.1	0.1

Model A is located in profile F-F´[4] at latitude 42.2 ºN. The region is caractherized by a high seismic velocity value ascending to the surface. At 6 km depth it is possible to identify na impermeable layer with zero porosity. A temperature value of 160 º C was considered as water temperature of 6 km depth. No heat production was associated with water in the region. Thermal conductivity and heat sources were calculated for each layer taking into account porosity values.

Model C- Ourense

Depth (Km)	Thermal conductivity K (W $k^{-1}m^{-1}$)	Heat production by radioactive elements A (μW m^{-3})
0-7	3.27	4.5
7-18	2.50	2.0
18-21	2.4	1.9
21-28	2.1	0.1

The relationship between geoid height and heat flow in the region



Heat flow density and heat production values

Model	Q_o (mW m^{-2})	Q_c/Q_o	A_0 (μW m^{-3})
A	85.7	0.59	4.5
B	89.5	0.61	4.5
C	95	0.63	4.5
D	96.5	0.64	5
E	85.5	0.59	4

Surface altitude and information from geotherms

Model	Altitude (m)	CPD (Km)	LT (Km)	CT (Km)
A	100	28	96	28
B	462	27	96	27
C	385	27	96	28
D	526	28	96	30
E	59	28	96	30

Discussions & Conclusions

It is possible to obtain heat flow density values in regions not affected by ascending waters, with the method presented. The differences in heat flow values at the surface are mainly due to heat sources in the crust and thickness of their layers. A velocity seismic anomaly “yellow zone” and the heat flow density value obtained in this zone may be explained by a low-density value (mass deficit) and lower heat production and thermal conductivity in crustal layers with water in the region. Q_C /Q_o values obtained in the present work belongs to the range obtained in similar regions in Portugal. Model D presents highest values found in the work but the influence of the layer thickness is visible in models A, B and C with the same value of heat production at the surface (A_o) but with different values of heat flow at the surface and heat generated in the crust (Q_C). Q_C values are similar in models E and A but they are associated with very different backgrounds. Equal values of CPD (Curie Point Depth) and LT (Lithosphere Thickness) were found in other regions of Portugal. A linear relationship between the heat flow density value at the surface and the geoid height was found in this work and a similar relation was found in the Beiras region located SE of this region near the border with Spain. The heat flow density value at the surface obtained with model A is different from the value obtained in other works but different types of data obtained in the region were used in the present work. The heat flow values obtained agree with values found in the Beiras region and in the southern part of Portugal.

[4] I. Veludo, N. Dias, P. Fonseca, L- Matias, F. Carrilho, C. Haberland and A. Villaseñor, “ Crustal seismic structure beneath Portugal and Southern Galicia (Western Iberia) and the role of Variscan inheritance,” *Tectonophysics*, vol 717, pp. 645-664, 2017.