SedDARE-IB: An open access repository of sediment data for Iberia and its continental margins

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Abstract

Sediments provide valuable information for geologists and geophysicists whenever they strive to understand, and reproduce, the geological evolution, lithology, rock properties, seismic response, and geohazards of a region. The analysis of sedimentary sequences is thus useful to the interpretation of depositional environments, sea-level change, climate change, and to a recognition of the sediments' source areas, amongst other aspects. By integrating sedimentary data in geophysical modelling, such interpretations are improved in terms of their accuracy and reliability. To help our further understanding of Iberia's geological evolution, geological resources and geohazards, this work presents to the scientific community the SedDARE-IB data repository. This repository includes available data of the depth to the Base Cenozoic and Top Paleozoic stratigraphic markers for the Iberian Peninsula and surrounding Western Atlantic and Mediterranean Neogene basins, or to the acoustic basement as interpreted for the Valencia Trough and Alboran Mediterranean basins. As an example of the broad applicability of the data included in SedDARE-IB, we investigate how sediment thickness affects the depth to the 150°C isotherm at specific basins, as commonly used in geothermal exploration. The calculated trend suggests that, given constant measured surface heat flow and thermal conductivity, the 150°C isotherm becomes shallower as a function of sediment thickness, until a critical threshold value is reached for the latter.

SedDARE-IB database has been built thanks to a Portuguese-Spanish collaboration promoting open data exchange among institutions and research groups. SedDARE-IB is freely available at https://doi.org/10.20350/digitalCSIC/16277 (Torne et al., 2024) bringing opportunities to the scientific, industrial, and educational communities for diverse applications.

1. Introduction

40   Sediments are crucial in our understanding of the geological evolution, lithology, rock properties, subsurface structure, georesources and geohazards affecting particular basins and regions. By analyzing strata and their architecture, geologists can decipher past environmental conditions, changes in the sea level, climate variability and the nature of the rocks sourcing them, amongst other factors. Their thickness is often indicative of the presence of important resources such as oil, gas or minerals. Also, sedimentary

45   rocks encompass a wide range of lithologies with distinct physical and mechanical properties, whose detailed knowledge is essential in geophysical models. Incorporating sedimentary data in geophysical modelling enhances the accuracy and reliability of subsurface models for subsequent resource exploration. In addition, sediments can contribute to the triggering of multiple geohazards, e.g. landslides, soil liquefaction and local seismicity, which they may amplify. By studying properties such as cohesion, shear

50   strength and degree of compaction in sediments, one can assess potential geohazards in a region and develop proper mitigation strategies.

Sediment data curation is instrumental for scientific research and holds cultural significance, offering glimpses into human history and the development of morphotectonic landscapes over time. Overall, sediment data curation is integral for advancing knowledge, sustainable resource management,

55   environmental protection, and making informed decisions in diverse scientific, economic and social fields. To facilitate our understanding of Iberia's geology, resources and hazards, this work presents SedDARE-IB as a comprehensive repository of: a) depth to the base of the Cenozoic strata deposited in both extensional and compressional basins, and b) the top of the Paleozoic units for the majority of sedimentary basins spanning the onshore and offshore of Iberia. SedDARE-IB includes sedimentary data on onshore

60   basins as varied as the foreland basins of the Pyrenean-Cantabrian Orogen (Ebro and Duero basins) and Betic Cordillera (Guadalquivir Basin), the Tagus Basin and the Lusitanian and Lower Tagus basins, and many other small basins whose location is shown in Figs. 1b and 2. Offshore, SedDARE-IB comprises data from the Atlantic Margin (Alentejo, Peniche, Northern Lusitanian Basin and deep offshore depocentres), the Gulf of Cadiz region (Algarve Basin and its surroundings) and the base of the Cenozoic

65   marker for the Western Mediterranean Neogene basins, e.g., Valencia Trough and Alboran Basin, also comprising the acoustic basement for the rest of the Western Mediterranean region (see Figs. 1b and 2 for location).

As an example of the applicability of the SedDARE-IB data we analyze the depth of the 150ºC isotherm for different surface heat-flow density values. Sediments play a crucial role in geothermal energy

70   assessments as they serve as a natural insulating layer, regulating heat transfer between the subsurface

and Earth's surface. Hence, we examine in this work how sediment thickness influences subsurface temperature. SedDARE-IB can be used in geothermal studies as sediments influences heat conduction, reservoir evaluation, temperature distribution, drilling considerations, thermal conductivity, heat flow modeling, resource assessment, and environmental impact assessments. Understanding sediment

75 thickness is therefore essential for an effective planning, development and use of geothermal energy resources.

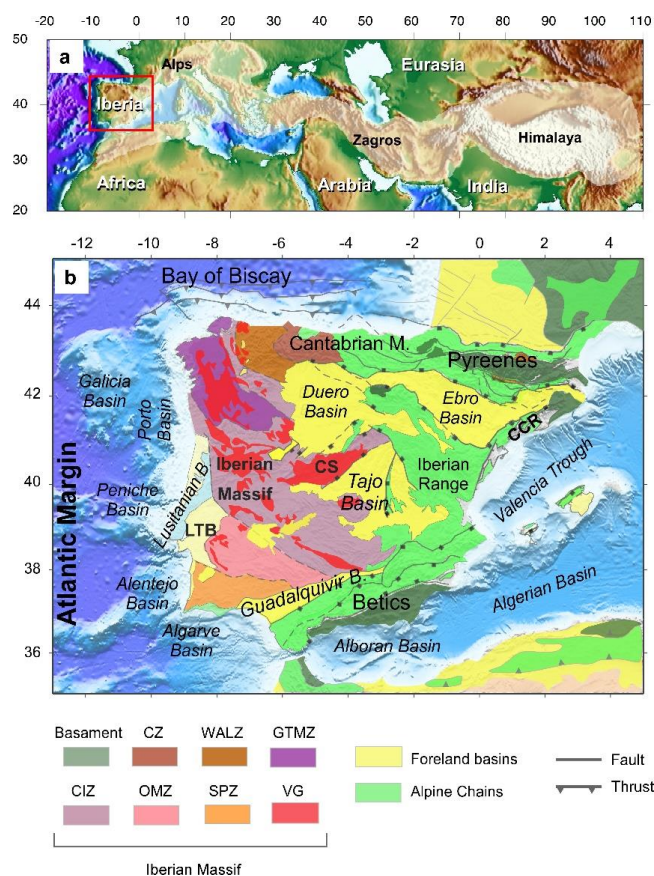
Data included in SedDARE-IB are listed in Table S1, together with the main sources of information from which the data have been gathered, the geological areas covered, and the main references related to the data sets.

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Figure 1 (a) Elevation map of the Alpine-Himalayan Orogenic Belt as shown by the shaded area. Red square highlights the location of the Iberian Peninsula and surrounding margins. (b) Simplified geological map of the Iberian Peninsula. Iberian Massif abbreviations: CZ: Cantabrian Zone, CIZ: Central Iberian

Zone; GTMZ: Galicia-Tras-Os-Montes Zone, OMZ: Ossa Morena Zone; SPZ: South Portuguese Zone;
85   VG: Variscan Granitoids, WALZ: Western-Asturian-Leonese Zone. Other abbreviations: Cantabrian M.:
Cantabrian Mountains, CCR: Catalan Coastal Ranges, CS: Central System, Guadalquivir B.: Guadalquivir
Basin, LTB: Lower Tagus Basin. Adapted from Torne et al. (2015, 2023).

2. Geological outline of the Iberian Peninsula and its adjacent continental margins.

2.1 The Iberian plate during the Alpine Wilson Cycle

90   The Iberian Plate, presently attached to Europe along the Pyrenean orogenic system, constitutes the
westernmost segment of the 12,000 km long Alpine–Himalayan Orogenic Belt, which was shaped as a
result of the Late Cretaceous–Cenozoic closure of the different branches of the Tethys Ocean. Such a
process resulted in the continental collision of Africa, Arabia and India with Eurasia (e.g., Dercourt et al.
1986; and many others). During the Variscan Orogenic Cycle, the relatively small Iberian Plate was
95   located in a hinge region between Pangea and Gondwana, with its northern and southern boundaries
marked by large transfer faults - currently the Pyrenees and Betic orogenic systems. In spite of having
been relatively bound by the larger Africa and Eurasian plates, the Iberian Plate evolved independently
for hundreds of millions of years, a character that shaped its fairly complex Variscan and Alpine systems
of basins and mountain chains. Comprehensive data on Iberia's Variscan evolution are given in Friend
100   and Dabrio (1996), Gibbons & Moreno (2002), Vera et al. (2004) and Quesada & Oliveira (2019).

Permian and Triassic continental rifting in the proto-Atlantic domain culminated with the opening of the
Central Atlantic Ocean south of Iberia, with subsequent transtensional motion of Africa and opening of
the Ligurian-Tethys at c. 156 Ma (Late Jurassic - Vergés and Fernàndez, 2006). This Jurassic oceanized
lithosphere shaped the boundaries of Iberia by developing the rift-related Algarve, Prebetic and Subbetic
105   basins to the south, and also the Catalan basin to the east. Such basins were later included as part of the
Betic and Catalan Coastal Ranges orogenic systems. The northern propagation of the southern North
Atlantic at about 118 Ma (Early Cretaceous) occurred along the Iberian Atlantic margin and led to the
formation of large rift-related basins of Permo–Triassic and Jurassic–Lower Cretaceous age. Such basins
were developed along the Iberian Atlantic margin and form the Alentejo, Lusitanian, Peniche, Porto,
110   Galicia Bank basins (Fig. 1).

The opening of the Central and Southern North Atlantic segments initiated the fairly synchronous
eastwards drift of both Africa and Iberia with respect to Eurasia along the inherited Variscan northern
boundary of Iberia, a phenomenon that started in the Early Cretaceous and ended in the late Santonian
time at around 83.5 Ma (Macchiavelli et al., 2017). The salt-related, transtensional Basque-Cantabrian

115 basin mostly evolved during this time (Cámara, 2017), together with the Organyà (Casini et al., 2023) and the North Pyrenees basins (Ford and Vergés, 2021).

North-south convergence between Africa and Eurasia started at 83.5 Ma and is still active at present. Africa-Eurasia convergence resulted in significant deformation within Iberia, and affected the previous Iberian Mesozoic rift-related basins. Along the northern margin of Iberia, the Pyrenees Range emerged

120 because of continental collision and limited northward subduction. In the southern margin of Iberia - a more complex region involving the Betics and Rif mountain ranges, the Alboran Sea, and the Gulf of Cadiz - formed the subduction-related Betic-Rif orogenic system. The interior of Iberia was also shortened, mostly along relatively weak intra-continental regions associated with Mesozoic rifting. This triggered tectonic inversion in the E-W Basque-Cantabrian Basin, the NW-SE Iberian and Altomira

125 ranges, the NE-SE Central System and the NE-SW Catalan Coastal Ranges (Muñoz-Martín and De Vicente, 1998; Vergés and Fernàndez, 2006; Casas-Sainz and Faccenna, 2001). All these inversion-related fold-and-thrust systems are linked at their respective connection zones where distinct fold trends coexist. The smooth variations in structural trends among compressive fold-and-thrust belts, as illustrated in the Iberia Geological Map at the 1:1,000,000 scale (Rodríguez-Fernández et al., 2015), suggest their

130 simultaneous occurrence, at least to some extent (Anadón and Roca, 1996; Casas-Sainz and Faccenna, 2001; Vergés and Fernàndez, 2006). In such a regional context, the western margin of Iberia along Portugal also shows mild inversion tectonics, which becomes more significant towards the south (e.g., Alves et al. 2003; Zitellini et al. 2004; Terrinha et al, 2009; Ramos et al., 2016; Cunha et al., 2019; Alves, 2024).

135 **2.2 Iberia mainland**

In mainland Iberia, the SedDARE-IB data were organized in six (6) major areas: a) the Pyrenees and Ebro Basin (PE), b) the Duero and the Basque-Cantabrian basins (DB), c) the Iberian Range and the Tagus and Almazán basins (ITA), d) the Guadalquivir Basin and the External Betics (GB), and the Lower Tagus Cenozoic Basin (LTCB) (Fig. 2). For the Top Paleozoic marker, the Ebro Basin domain and Tagus and

140 Almazán basins area have been expanded to the Southern Pyrenees and the Iberian Range, respectively. (Fig. 2). Figures 3 and 4 show the location of the points and seismic profiles included in the database, while Figs. 5 and 6 are an example of the grids generated from the database.

1: Offshore Atlantic Margin
2: Lines off Portugal
3: Offshore & Alentejo-Algarve basins
4: Offshore Lusitanian Basin
5: Western Mediterranean

PE: Pyrenees & Ebro Basin
DB: Duero & Basque-Cantabrian basins
ITA: Iberian Range and Tagus & Almazan basins
BG: Betics Range and Guadalquivir and South Tagus basins
LB: Lusitanian Basin
LTB: Lower Tagus Basin

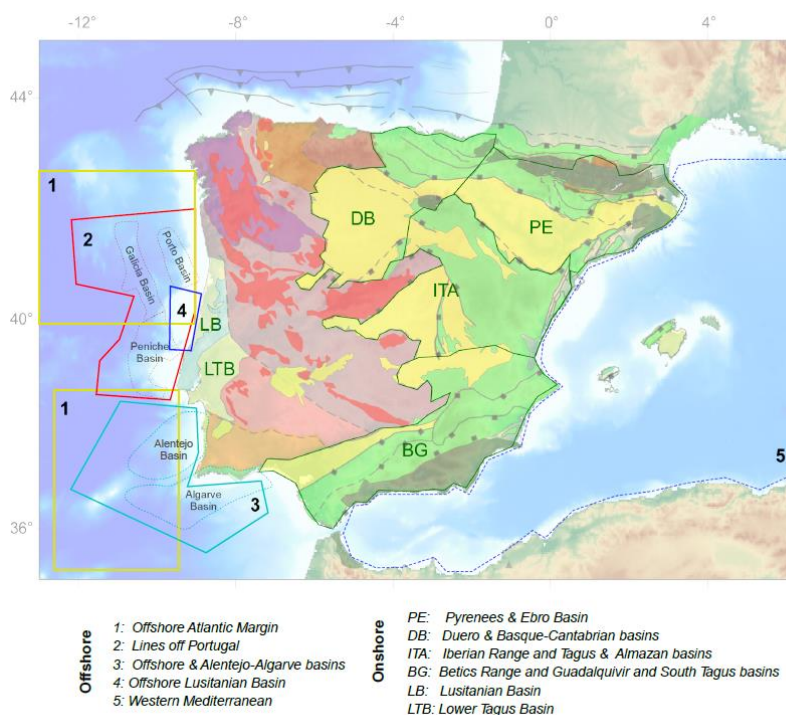



Figure 2 Simplified geological map showing location of the data sets listed in Table S1. Modified from
Torne et al. (2015).

2.2.1 Ebro Basin (EB)

The Ebro Basin, spanning approximately 85,500 km^2, is limited by the Pyrenees and the Basque-
Cantabrian Fold Belt to the north. The basin represents the latest evolution stage of the long-lived
evolution of the Southern Pyrenean foreland basin, which has lasted from the latest Cretaceous until the
present day. The Ebro Basin displays an irregular geometry in map view since it is also limited by the
Catalan Coastal Ranges to the SE and the Iberian Range to the SW. The basin records a long-lasting
evolution; was first originated as the Pyrenean foreland basin, and was later filled with shallow- to deep-
marine deposits along a tectonic trough that was subparallel to the southern front of the Pyrenees
(Puigdefàbregas et al., 1992). The basin changed to an endorheic system at approximately 36 Ma as the
Western Pyrenees marine gateway was closed (Costa et al., 2010). Alluvial, fluvial, and lacustrine
depositional systems prevailed until the middle to upper Miocene (García-Castellanos et al., 2003).

The Ebro Basin remained endorheic for about 27 million of years until the Oligo-Miocene opening of the Western Mediterranean basins. This opening triggered the formation of a Mediterranean river system, leading to the capture of its drainage network (Lewis et al., 2000). It also caused significant denudation; an area of 25,000 to 45,000 km² was eroded at a rate of 47-80 mm/kyr, a phenomenon that resulted in the subsequent isostatic rebound of the basin by up to 630 m (García-Castellanos and Larrasoaña, 2015). The depositional record of this erosion is found in the Castellón Group of the Valencia Trough (Martínez Del Olmo, 1996; Arche et al., 2010).

2.2.2 Duero and the Basque-Cantabrian basins (CD)

The Duero Basin, with an area of approximately 98,500 km², is bounded by several mountain ranges and is one of the highest Alpine intra-mountain basins in Europe (Casas-Sainz and De Vicente, 2009) (Fig. 1B). Its average altitude is in excess of 800 metres. It contains a thicker sedimentary infill in its northern sector, associated with the Alpine fronts of the inverted Basque-Cantabrian Basin and the Alpine reactivation of the Variscan Cantabrian Range. This fill gradually thins outs towards the southern and western boundaries of the basin, on Variscan basement rocks (Civis and Vera, 2004; Herrero et al., 2004; Quesada et al., 2019). Sediment infill above Mesozoic deposits varies across different geological epochs, with changing thicknesses and areal extents. Notably, the youngest sedimentary infill in the basin correlates to the top of the fluvial–lacustrine carbonates of the Páramo Formation, which are dated to about 9.6 Ma (Krijgsman et al., 1996; Cunha et al., 2019). The opening of the Duero Basin to the Atlantic Ocean occurred in late Pliocene to Pleistocene times, with further incision occurring later. The exact timing of this opening is still debated, with some suggesting it occurred around 1.1–1.9 Ma, while others propose it might have happened earlier, in the middle Tortonian. Regardless of its age, the opening of the Duero Basin to the Atlantic Ocean marked a significant reorganization of fluvial networks within it (Antón et al., 2012, 2019; Silva et al., 2016; Struth et al., 2019 and 2021).

2.2.3 Tagus and Almazán basins (TAB)

The Tagus Basin, located in the center of the Iberian Peninsula and covering approximately 20,000 km², is bordered by the Central System to the north, the Iberian System to the east, and the western sector of the Montes de Toledo to the south. It comprises two distinct sub-basins: the intra-mountainous Madrid Basin and the Loranca (also known as the Intermediate Depression), which comprises a piggy-back depocenter in the eastern part of the Tagus Basin. These basins were individualized due to tectonic uplift of the Sierra de Altomira during the late Paleogene, and their Cenozoic evolution was influenced by tectonics and climate change (Alonso-Zarza et al., 2004). Sediments in the Tagus Basin consist of

Paleogene shales, gypsum, conglomerates and limestones predominantly formed in alluvial fan systems alongside evaporitic lakes and lacustrine marls. Miocene sediments comprise alluvial fan and lacustrine facies, which are capped by lacustrine limestones and Pliocene detrital sediments. The Intermediate Depression is a narrow depocentre located to the east of the Madrid Basin, and contains Upper Cretaceous shales and gypsum, younger alluvial and lacustrine fan intervals, fluvial and floodplain sediments, and Pliocene lacustrine sands and limestones (Paramo limestones) alongside other detrital materials (Alonso-Zarza et al., 2004; De Vicente et al., 2004).

2.2.4 Lower Tagus Basin (LTB)

The Lower Tagus Basin is surrounded by Mesozoic sediments of the Lusitanian Basin to the west and pre-Mesozoic igneous and metamorphic rocks to the east. The basin is exclusively Cenozoic in age and sits on Cretaceous strata in its southern part, Middle Jurassic units in its northern part, and Paleozoic rocks in its eastern part. Paleogene continental strata, 200-400 m thick, accumulated first in the basin during the Late Eocene and Oligocene in response to NNE-SSW convergence of Iberia and Africa (Carvalho, 1995; Cabral et al., 2003). Miocene tectonics overprinted the Paleogene structures, with the LTB evolving as a compressive foredeep basin related to tectonic inversion of the Lusitanian Basin under NW-SE compression. Miocene strata, exceeding 800 m in local depocenters near Lisbon (Cabral et al., 2003), include sandstones, clays and limestones deposited in shallow marine, mixed lagoonal, shallow water and continental environments (Pais et al., 2012). Tectonic subsidence in the basin slowed down during the Pliocene, as marked by the deposition of about 300 m of fluvial sediments, mainly sands and clayey or silty sands. Tectonic uplift predominated after the Early Pleistocene, while sands and clays topped by levels of pebbles are typically found in Pleistocene strata. These are overlain by Holocene alluvium deposited by the Tagus River. Tectonic compression continues to the present day, with maximum horizontal compressive stress trending NW-SE to WNW-ESE (e.g. Ribeiro et al., 1996; Borges et al., 2001).

2.2.5 Guadalquivir Basin (GB)

The Guadalquivir Basin, located in the southern part of the Iberian Peninsula and spanning c. 57,000 km², is a foreland basin bounded to the north by the Iberian Massif and to the south by the Betic Cordillera, which continues into the Rif Chain of northern Africa. Similarly, to the westernmost part of the Betics, it was influenced by post-Cretaceous tectonic movements between Africa and Eurasia. Studies suggest significant N-S convergence to have affected the Guadalquivir Basin from mid-Oligocene to the late Miocene, followed by WNW-directed oblique convergence until the present day (Macchiavelli et al.,

2017). The basin comprises six (6) Miocene seismic-stratigraphic sequences that are overlain by Pliocene-
220 Quaternary strata that record westward sediment progradation along the basin axis (Berástegui et al., 1998). The southern border of the basin comprises several salt diapirs, with Triassic evaporates in their core, that were tectonically compressed during the Cenozoic. They form multiple frontal imbricate wedges. Tectonic activity, including normal faulting at basement level, occurred during early to middle Serravallian times. The basin primarily originated through orogenic wedge accretion along its active
225 southern margin, with flexural subsidence propagating towards the foreland basin per se (García-Castellanos et al., 2002). Readers are directed to the work of Civis et al. (2004) and Barnolas et al. (2019) for further detail on the basin's sedimentary infill and evolution

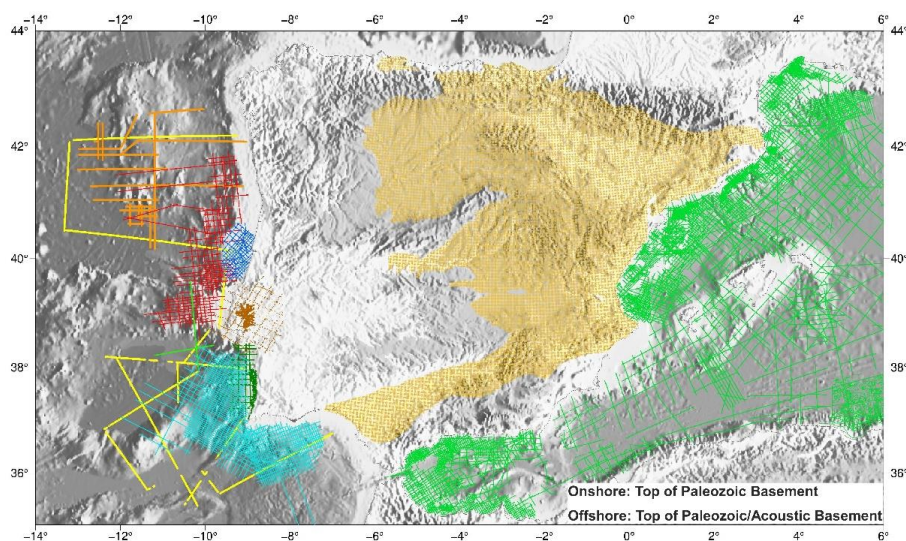



Figure 3 Offshore: Location of seismic profiles used to interpret and gather data for the Top Paleozoic
230 marker, or Acoustic Basement marker for most of the Western Mediterranean region. Base Cenozoic marker. Onshore: location of x,y,z data obtained from available seismic, log data and geological information

2.3 Iberian offshore basins

2.3.1 West Atlantic Margin

235   The West Iberian Margin is, essentially, a divergent margin reactivated tectonically since the end of the
       Cretaceous. It witnessed continental rifting from the Late Triassic to the Early Cretaceous. Diachronous
       continental breakup along this margin occurred over a period spanning from the latest Jurassic to the
       Albian/Cenomaniann (Alves and Cunha, 2018). Breakup propagated from southwest to north Iberia,
       extending towards the Bay of Biscay (Grevemeyer et al., 2022). Two main episodes of magmatism are
240   recorded during this process: the first around 200 Ma (Hettangian) associated with the Central Atlantic
       Magmatic Province (CAMP), and the second during the Valanginian period at 135-130 Ma (Martins et
       al., 2008).

       Post-rift magmatism occurred after 80 Ma (Campanian) and was predominantly alkaline. It is recorded
       onshore by sub-volcanic complexes near Sintra, Sines, and Monchique, with volcanic complexes also
245   present near Lisbon and offshore Algarve (Terrinha et al., 2009). Also, onshore, Lower Cretaceous
       magmatism has been dated as spanning 94 to 69 Ma in Portugal, and occurring at c. 79 Ma in northeast
       Spain (Ubide et al., 2014).

       At present, the continental slope of Iberia dips abruptly to the west in its northwest part but is gentler in
       its central and southwest parts due to the accumulation of thick Cretaceous-Cenozoic strata (Alves et al.,
250   2009). Late Cretaceous-Cenozoic exhumation and erosion are evident, particularly on the proximal part
       of the slope (Terrinha et al., 2002; Pereira et al., 2013; Alves, 2024). The Estremadura Spur, separating
       southwest Iberia from its northwest part, has experienced significant post-rift tectonics and magmatism
       (Miranda et al., 2009), associated with compressional tectonics and tectonic inversion (Ribeiro et al.,
       1990) (Fig. 1).

255   In summary, the West Atlantic Margin features a relatively narrow, westerly-tilted continental shelf, with
       major rivers contributing sediment north of 41°N. Sediment accumulation is significant in estuaries south
       of this latitude (Dias and Nittrouer, 1984). During sea-level lowstands, sediment bypass the shallower
       zones of the margin through large submarine canyons, leading to reduced terrigenous sediment
       contribution to the outer shelf region (Dias and Nittrouer, 1984, Dias et al., 2002). Sediment composition
260   on the shelf varies with depth, from fine micaceous sand at shallow depths to biogenic carbonate at greater
       depths (Dias and Nittrouer, 1984). The shelf edge comprises rocky outcrops and fine-grained sediment,
       resembling the gentler Alentejo continental margin (Drago et al., 2000). The continental slope is narrow
       and steep, bounded by north- to north-northeast-trending faults (Mougenot, 1989), except for the wider
       and structurally deformed Estremadura Spur. The continental rise is relatively wide, featuring multiple
265   seamounts and prominent fault-bounded depressions between seamounts where sediment transported by
       submarine canyons is accumulated (Mougenot, 1989; Alves et al., 2003).

2.3.2 Alentejo Basin

The offshore Alentejo region is characterized by its broad continental shelf, which blends with a gentle continental slope (~0.5°) due to thick Cenozoic sediment deposition west of 10ºW (Mougenot, 1988). Steeper gradients (>2°) occur near seamounts in areas of localized deformation (Coppier and Mougenot, 1982, Mougenot, 1988; Alves et al., 2003). Alves et al. (2003) recognized three main types of Cenozoic deposits on the Alentejo Margin: shelf-related, turbidite, and contourite/canyon-fill. A wide range of sedimentary deposits, from deep marine turbidites to fluvial/deltaic sequences (Shanmugam and Moiola, 1988) has been identified on seismic data crossing the continental slope of Alentejo. However, dredge samples near the shelf break contain shallow marine to shelf-break limestones rich in foraminifera (Mougenot et al., 1989). Deep-marine deposits, including mass-flow and channel-fill deposits, are common in more distal parts of the margin, while shallow-marine breccias are common on the continental slope (Mougenot et al., 1989, Coppier and Mougenot, 1982).

The Alentejo Basin, structured during the Upper Jurassic, is delimited by the Setúbal and São Vicente canyons. Limited exploratory drilling has revealed Hettangian-Triassic evaporites, suggesting the Alentejo Basin to constitute the southern continuation of the Lusitanian Basin (Mougenot, 1989). Extensive Late Cretaceous magmatic activity led to the emplacement of the Sines and underwater Côvo igneous complexes (Neres et al., 2023) when crustal extension shifted to compression tectonics, reactivating crustal faults (Alves, 2024). Several compressional pulses with different directions affected the region, driven by interactions between Iberia, the Nubia microplate, and the larger European and African tectonic plates (e.g., Juarez et al. 1998; Rosenbaum, 2002; Vissers and Meijer, 2012).

2.3.3 Algarve Basin

The Algarve Basin, located in southwest Iberia, originated during Mesozoic rifting due to the Neo-Tethys opening; it later experienced tectonic inversion during the Alpine orogeny (Terrinha et al., 2019). This basin trends E-W and extends for about 150 km, reaching a maximum width of 25 km in its onshore portion and about 100 km offshore. Bounded by Carboniferous basement rocks to the north and the Guadalquivir Bank to the south, crustal extension was accommodated by N-S and NE-SW structures in the westernmost part of the basin and ENE-WSW to E-W structures in the central and eastern parts. N-S to NW-SE striking faults bound main grabens and half-grabens (Terrinha et al., 2019; 2022). Five main extensional episodes occurred from Late Triassic to Cenomanian times and were interspersed with transient compressive events that resulted in depositional hiatuses throughout the basin.

Paleozoic rocks below the Algarve Basin consist of low-grade metamorphic rocks (shales and graywackes) part of the Baixo Alentejo Flysch Group. In the basin per se, the oldest deposits are Lower Triassic in age (red mudstones) overlain by conglomerates and red clays of the "Silves sandstones"

300   (Palain, 1976). Mesozoic sedimentation followed and is characterized by alternations of carbonate and siliciclastic facies, indicating shallow marine to continental environments. Tectonic inversion, occurring in the Algarve Basin since the Late Cretaceous, resulted from oblique convergence between northwest Africa and Iberia, causing important depositional hiatuses and unconformities. Offshore, the oldest Cenozoic deposits are Paleocene to Oligocene in age and lie unconformably over folded Lower

305   Cretaceous strata (Terrinha, 1998; Lopes et al., 2006; Roque, 2007, Matias, 2007)

Neogene strata overlay folded and thrusted older units, suggesting that tectonic inversion occurred predominantly after the Cenomanian and lasted until the late Oligocene-Aquitanian. Present-day compression is NW-SE oriented, driven by oblique collision between northwest Africa and southwest Eurasia (Ribeiro et al., 1996).

310   Figures 3 and 4 show the location of the points and seismic profiles included in the database, while Figs. 5 and 6 are an example of the grids generated from the database.

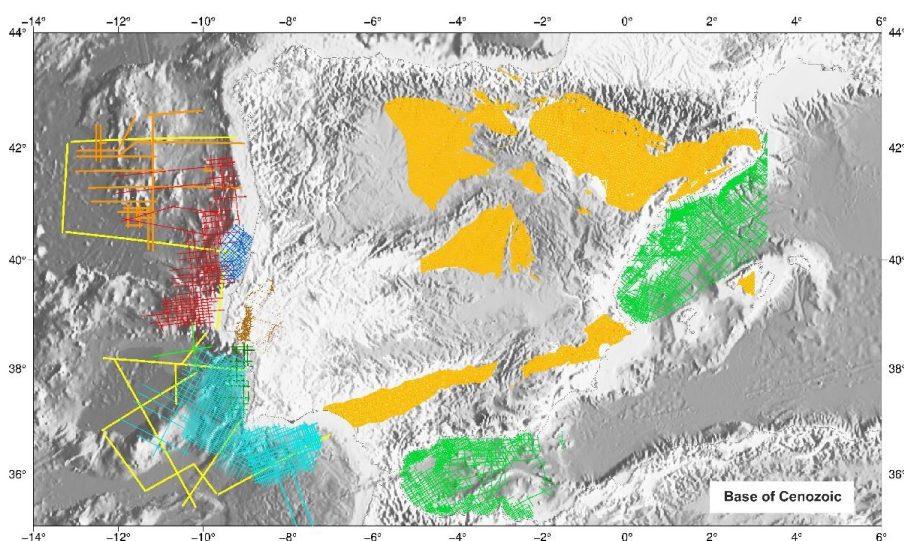



Figure 4 Offshore: Location of seismic profiles used to interpret and gather data on the Base Cenozoic marker. Onshore: location of x,y,z data obtained from available seismic, well log data and geological information. Main references from which data have been gathered are shown in Table S1. Additional references can also be found throughout the text.

3. Technical aspects of the data

3.1 Iberia mainland

The compilation of the Top Paleozoic and Base Cenozoic stratigraphic markers for the Spanish sedimentary basins has been carried out by the Instituto Geológico y Minero de España (IGME), complemented with a significant number of subsurface information from the Hydrocarbons Service of the former Ministry of Industry, Tourism, and Commerce (ATH), as well as studies from Empresa Nacional de Residuos Radioactivos SA (ENRESA), Universities, Associations, Working Groups, and Research and Development projects stemming from the ALGECO2 project (García-Lobón, 2010a). The objective of the project was the selection and characterization of areas and structures favorable for CO_2 storage of in Spain. Location of data points and seismic profiles included in the database are shown in Figs. 3 and 4.

For that purpose, the analysis and geoscientific information included a review of about 50,000 km of seismic lines and 400 exploration wells, in addition to the available regional cross-sections and subsurface maps largely derived from historical petroleum exploration. For further details on the digital geological reference mapping, data from oil wells, seismic data, reference surfaces, and other information, the reader is referred to the work of García-Lobón et al. (2010a) and references therein.

3.1.1 Ebro Basin

Data on the Ebro Basin was extracted mainly from regional and geological studies at various scales, including the MAGNA Projects, and from geological maps at a 1:400,000 and 1:50,000 scale. Additionally, geophysical information and deep drilling data were considered together with information gathered in the "Documents on the Subsurface Geology of Spain (IGME 1992)" (7 documents) and the Subsurface Geology of Spain (ITGE). IGME's geophysical Information, all drilling documentation (Composite and Master logs) from hydrocarbon exploration in the Technical Archive of the Ministry of Industry (which contains information of mining boreholes with depths up to 2500 m and oil boreholes with depths up to c. 5400 m), as well as the deepest boreholes from the Database of the Ebro Hydrographic Confederation, with depths up to 1658 m, which were re-analyzed in this work. In addition, over forty PhD and MSc-level theses, along with more than a hundred research articles were re-examined, with

particular focus on those completing regional structural analyses and geological cross-sections. This approach was especially relevant in regions with limited well data such as the shoulder areas of the Ebro

345 Basin. Other data sources such as the databases of CHE (Ebro Hidrogaphycal Confederation), Gessal, Repsol, Enresa, Union Texas, etc., were also consulted, providing relevant data for updating previous published maps. Subsequently, the interpretation of seismic lines and wells, in accordance with these cross-sections, led to the generation of maps of the depth contours (isobaths) presented in this study.

As pointed out by García-Lobón et al. (2010b), the isobath map of the Base Cenozoic stratigraphic marker

350 is not consistently defined du to discrepancies arising from both multiple unconformities in syntectonic depositional sequences and potential blind thrusts along the boundaries of the basin. These makes difficult the correlation between subsurface and surface outcrops. For a complete list of references and technical details, the reader is referred to the work of García-Lobón et al., 2010b.

3.1.2 Duero and Basque-Cantabrian basins

355 Isobath maps for these two basins were compiled based on information from 239 hydrocarbon exploration wells reaching depths between 500 m and >2500 m. The available borehole data allowed the identification of multiple stratigraphic tops in the Mesozoic sequence. Additionally, reference points from regional cross-sections and isobath data from previous work were used to create differing isobath maps. Using these same data sets, contour lines were generated and later edited to test the presence (and effect) of

360 multiple geological structures based on the existing geological and structural data for the Basque-Cantabrian and Duero Basins. This process allowed the creation of isobath maps for the Base Cenozoic base and Top Paleozoic markers, adjusting them to main faults and structures identified in regional geological maps. For the eastern and northeastern part of the Duero Basin, the calculated isobaths include subsurface information from oil exploration wells. For a complete reference list and additional technical

365 details, the reader is referred to García-Lobón et al. (2010c).

3.1.3 Tagus-Almazán basins

For the creation of isobath maps in the Iberian Chain and the Tagus and Almazán Basins, two different approaches were developed based on the available data on these two Tertiary basins, their reliability, and distribution. Thus, data presented in this study for these areas were mainly constrained by geological

370 cross-sections, as there was a scarcity of subsurface data and from available reflection seismic cross-sections and borehole information. An effort was made to ensure the consistency of all final products at the regional scale considered in this work.

Geological cross-sections were primarily sourced from pre-existing or new cross-sections, with the latter predominantly derived from boreholes and pre-existing isobath maps. Where there was a scarcity of data and structural information, i.e. in the Iberian Range, an effort was made to increase data density from surface cartography, boreholes and regional cross-sections. For a complete reference list and additional technical details, the reader is referred to (García-Lobón et al., 2010d).

3.1.4 Guadalquivir Basin

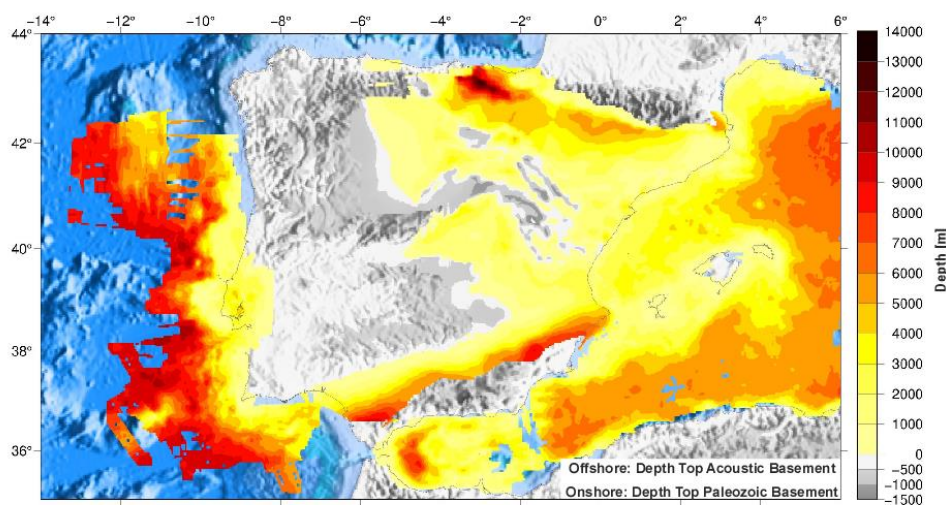
Stratigraphic information from the Guadalquivir Basin was gathered after re-assessing of surface and subsurface exploration data. Primary sources of this information were reports and databases from the IGME. This dataset was further enriched by substantial subsurface documents and data acquired from the Hydrocarbons Service of the former Ministry of Industry, Tourism, and Commerce, together with contributions from various public entities, universities, associations, and working groups participating in research and development projects, including the ALGECO2 project (García-Lobón, 2010a).

In addition to these data, regional geological cross-sections were compiled using the available geological maps and subsurface data, particularly those where seismic profiles and boreholes exist. Notably, the Guadalquivir Basin has limitations in terms of seismic grid coverage and borehole control, particularly when one considers the stratigraphic markers of interest to this work. Consequently, the accuracy of these isobath maps is variable across different locations. For a complete reference list and additional technical details, the reader is led to García-Lobón et al. (2010e).

3.1.5 Lower Tagus Basin

The depth to the Base Cenozoic marker in this area was obtained using seismic reflection data calibrated by exploration boreholes, by modeling land gravimetric data, and via geological outcrop data. Seismic reflection data comprise legacy surveys acquired with distinct geometries and sources for the oil industry from the mid 50's until 1982. These surveys were reprocessed and reinterpreted in Carvalho et al. (2005; 2017). Gravimetric data of the national Portuguese grid was also used to increase the geographical coverage of the existing seismic data, which was limited to the western part and central part of the Lower Tagus Basin (Carvalho et al 2017).

Seismic reflection data were used, where available, to determine the depth of the base of the Mesozoic, which was only reached by a few exploration wells. In contrast, aeromagnetic data were used across the entire basin (Carvalho et al. 2014). These datasets do not allow a precise estimate to the depth of pre-Mesozoic rocks; in fact, the acoustic basement in seismic data is often coincident with the Top Dagorda

salt member (Hettangian) (e.g., Watkinson, 1989; Carvalho et al., 2005; Alves et al., 2003) and,
405   occasionally, the Triassic Silves Formation. In the areas where the basement was estimated via magnetic
data models, errors are also expected due to the non-uniqueness of potential-field methods. Despite the
calibration of seismic and magnetic data with some sparse boreholes, depth errors in the top of the pre-
Mesozoic rocks may reach a few hundred meters in some areas.

410   **Figure 5** Offshore: Depth to the Top Paleozoic marker, or Acoustic Basement marker for the majority of
the Western Mediterranean region. Exceptions are the Valencia Trough and the Alboran Basin, where the
basement marker corresponds to the Base Cenozoic marker or the so-called Oligocene unconformity.
Onshore: Depth to the top of the Paleozoic Basement interpreted as the Paleozoic-cover sequence
boundary or Hercynian discordance (Garcia-Lobón et al., 2020 and references therein).

415   **3.2 Offshore Iberia**

3.2.1 West Atlantic margin

The interpreted 2D multi-client seismic reflection data corresponds to a reprocessed seismic grid acquired
from TGS during the PDT00 and PD000 cruises and from the IAM seismic survey profiles (IAM-4, 5, 8,
9, 10, 11, T1, T2, GB1, GB2, GB3). Details on the acquisition parameters and processing data for the two
420   cruises can be found in (TGS, 2001) and Banda et al. (1995) and Torne et al. (2018), respectively. Figures
3 and 4 show the location of seismic profiles included in the database.

The interpretation of the Base Cenozoic and Top Paleozoic markers is based on regional (2-D) seismic data together with unpublished outcrop and well data (Figs. 5 and 6). The new data are of good enough quality for interpreters to mark a Top Basement stratigraphic marker with confidence, though the real
425   morphology of such a basal horizon is somehow masked by the poor resolution of the data at its depth of occurrence. Nevertheless, the base of Meso-Cenozoic strata is clear on the new, reprocessed TGS data. In this work, the criteria of Driscoll et al. (1995), Sinclair et al. (1995), Alves et al. (2009) and Soares et al. (2012) were used in the identification of key tectonic events affecting the North Atlantic region. Therefore, the two stratigraphic markers mapped in the available dataset were correlated with borehole and outcrop
430   data acquired from published and unpublished information from the Lusitanian Basin (Atrops and Marques, 1986; Wilson et al., 1989; Hiscott et al., 1990; Alves et al., 2002, 2003; Dinis et al., 2008), Porto Basin (Moita et al., 1996), Iberia Abyssal Plain (Wilson et al., 1996, 2001; Eddy et al., 2017), and proximal NW Iberia (Groupe Galice, 1979; Boillot et al., 1989; Murillas et al., 1990, Tucholke et al., 2007).

Unpublished information from exploration wells Pe-1, Go-1, 20B-1, 5A-1 and Lu-1 in West Iberia,
435   together with dredge data published in Mougenot et al. (1989), were used locally to corroborate our seismic-stratigraphic interpretations. DSDP Site 398 and ODP Sites 637-641, 897-901 and 1065-1070 comprise important information used to correlate seismic-stratigraphic units across the study area (Fig. 1b). These data are complemented with information from DSDP Site 120 and IODP Sites U1385, U1391 and U1588 which recently drilled the SW Iberian margin (Hernández-Molina et al., 2013; Hodell et al.,
440   2023) (Fig. 1). All data were integrated in a Schlumberger's Petrel® project so that structural, magnetic and seismic stratigraphic data could be analyzed together.

3.2.2 Alentejo Basin (continental shelf)

The Top Basement and Base Cenozoic stratigraphic markers were gathered from the interpretation of the 1984 acquired GSI seismic reflection profiles (Carvalho, 1995), calibrated by available well data (GPEP,
445   1986), and geological outcrop information obtained from dragging and multi-channel seismic reflection data of Mougenot (1989). The seismic reflection data interpretation was assisted with gravimetric data (free air anomaly data collected also along the GSI profiles) and aeromagnetic data acquired in 1969 by Fairey Surveys Limited. Descriptions of the seismic and potential field datasets can be found in Carvalho (1995). Location of seismic lines included in the database are shown in Figs. 3 and 4.

450   Potential field data allowed the identification and separation of basement uprises or lows (pre-Mesozoic units), from salt and igneous structures. The structural interpretation obtained from seismic data was also compared with derivative maps of the gravimetric and magnetic anomaly maps, such as analytical

continuations to several altitudes, horizontal derivatives, vertical derivatives, shaded relief, etc. Seismic interpretation was used afterwards as a starting point for the joint 2.5D forward modeling of magnetic and

455 gravimetric data using freeware software (Webring, 1985). The base of the Mesozoic horizon was further corroborated by 3D gravimetric modeling using the software of Broome (1991), which uses the method of Plouff (1976).

3.2.3 Algarve Basin

The geophysical data used to define the Top Basement and Base Cenozoic markers consist of a high-

460 resolution marine gravity survey and a 2D regional seismic reflection survey (TGS, 2001) and represent a total coverage (58 lines; 5,820 km) of 17,890 km^2, extending from the shelf to the deep part of the Algarve Basin (Figure 2). The gravity data provided by TGS has been used to further constrain the top of basement data in areas where seismic data coverage was poor or lacked resolution. Well data provided by DGGE (Direcção Geral de Geologia e Energia) and from Lanaja et al. (1987) were used as constraints.

465 The seismic-stratigraphic framework was simplified and divided into four seismic–stratigraphic units based on their seismic character and well to seismic calibration (Matias, 2005; 2007), spanning from the Paleozoic basement to Late Cenozoic sediments. Mapping of the top of the basement was aided by the results from gravity enhancement maps and inversion (Matias, 2007). A time-to-depth conversion of the interpreted horizons was performed using a layer-cake approach, as detailed in Matias (2007). Location

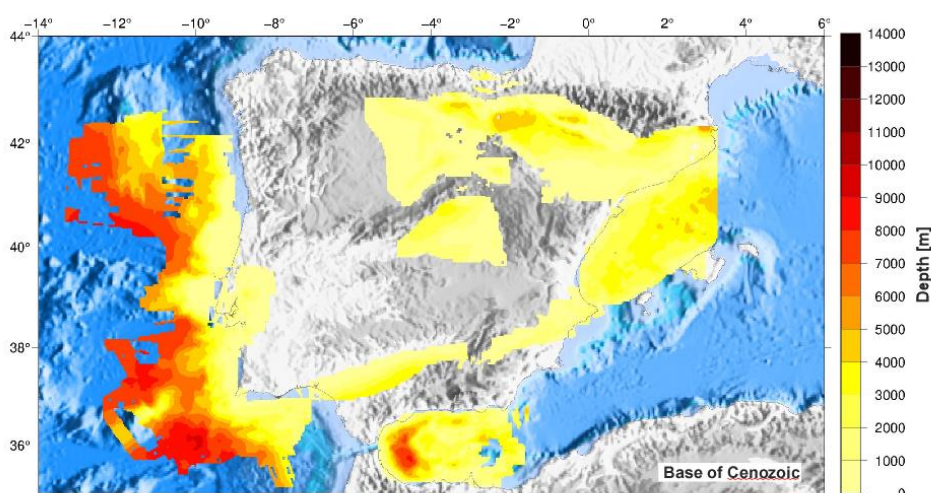
470 of seismic lines included in the database are shown in Figs. 3 and 4.

3.2.4 Western Mediterranean

Data of the depth to the acoustic basement for the Western Mediterranean region have been downloaded from SEOANE (Sea Scientific Open Data Publication; Bellucci et al. (2021), doi: 10.17882/80128). These data derive from the compilation and reprocessing, and in some cases digitalization, of available industry

475 and academia multichannel seismic profiles and well log suites. All these data have been acquired since the 1960's and cover the westernmost Mediterranean Neogene basins, namely the Valencia Trough and the Algerian and Alboran basins. As detailed in Belluci et al. (2021), the interpretation of the Top Basement marker extends across all geomorphological domains, ranging from the shelf to the deep basin (Fig. 2). It serves as the boundary separating the chaotic seismic facies of the substratum from the stratified

480 seismic facies of the sedimentary column. In the Alboran and Valencia basins, the Top Basement horizon coincides either with the Base Cenozoic or the so-called Oligocene unconformity, as documented in studies such as Do Couto et al. (2014), Pellen et al. (2016), and Etheve et al. (2016) (Figs. 3 and 4). For more detailed information the reader is referred to the work of Belluci et al. (2021) and references therein.

As the original data file presents different information relative to the age of the acoustic basement, we
485   split the original file into three subfiles corresponding to the Valencia Trough and Alboran Basin regions
(Base Cenozoic or the Oligocene unconformity) and the Algerian basin (boundary between chaotic and
stratified seismic facies). For more details, please refer to Table S1. Location of seismic lines included in
the database are shown in Figs. 3 and 4.

490   **Figure 6** Offshore and onshore depth to the Base Cenozoic marker. Main references from which data
have been gathered are shown in Table S1. Additional references can also be found throughout the text.

4. Influence of sediment thickness and nature on geothermal potential

While it is generally acknowledged that sediments can function as thermal insulators, impeding the
upward heat transfer from deeper layers, the thermal conditions at a specific site - including surface heat
495   flow, sediment and underlying layer thermal conductivity, and also radiogenic heat production - exert a
profound influence on subsurface temperature distribution. To investigate how sediments may influence
the thermal field, we have systematically calculated the variation in the depth of the 150ºC isotherm
considering variable surface heat flow values, sediment thickness, thermal conductivity variations, and a
fixed radiogenic heat production. Temperature profiles have been computed in one dimension,
500   considering surface heat flow values ranging from 40 to 120 mW/m^2, a range that is representative of the
mean and maximum heat-flow values recorded in the Iberian Peninsula. We have also considered standard
values of radiogenic heat production for sediments and crust at, respectively, 1 μW/m^3 and $3 \times e^{(z/10)}$

µW/m³. Other parameters considered were a crustal thermal conductivity of 3.1 W/mK and a mean surface temperature of 15ºC.

505 Figure 7 shows the variations in depth of the 150ºC isotherm concerning sediment thickness, surface heat flow, and four different thermal conductivity values for the sediments (panels Fig. 7A to D). The calculated trend suggests that, given a constant measured surface heat flow and constant thermal conductivity, the isotherm's depth decreases as sediment thickness increases until it reaches a critical threshold depth. Beyond this depth value, the isotherm is stable. Our results also show that, as expected,

510 for a specific value of thermal conductivity, an increase in surface heat flow results in the relative shallowing of the isotherm, while a decrease in surface heat flow produces the opposite effect. It is also interesting to note how the increase in thermal conductivity correlates with a greater deepening of the 150ºC isotherm for the same heat flow and sediment thickness values. Comparing Fig. 7A (showing the minima in conductivity values) and Fig. 7D (representing the maxima in conductivity values), one

515 observes that for a constant heat flow value, say 70 mW/m², the 150°C the isotherm is significantly deepened as conductivity increases. Additionally, we observe that changes in sediment thickness wield more influence at lower thermal conductivity values. For instance, is one assumes a thermal conductivity of 1.27 W/mK and a surface heat flow of 70 mW/m², the isotherm depth is reduced until sediment thickness reaches approximately 3.5 km. Beyond this point, the isotherm stabilizes at a constant depth

520 (Fig. 7A). Conversely, when assuming higher conductivity values, e.g. approaching the conductivity of the crust (e.g., 3.0 W/mK), the effect of any increase in sediment thickness is notably reduced (Fig. 7D).

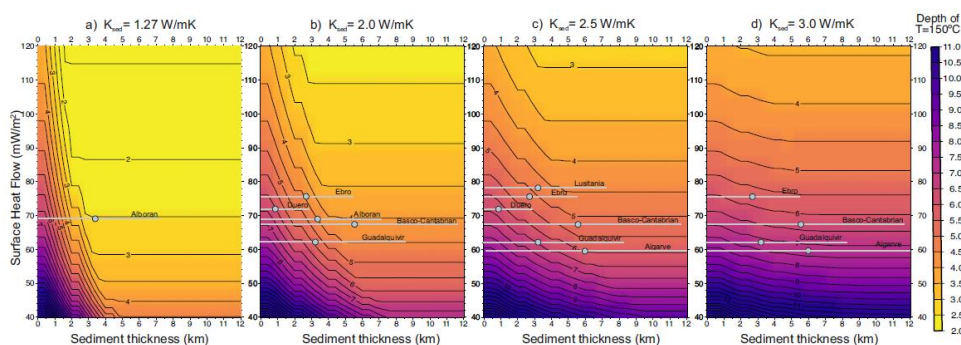



Figure 7 Depth to the 150ºC isotherm as a function of sediment thickness and surface heat flow, assuming four different thermal conductivities for sediments: (A) 1.27 W/m K, (B) 2.0 W/m K, (C) 2.5 W/m K and

525 (D) 3.0 W/m K. Crustal conductivity is kept constant at 3.1 W/m K. Radiogenic heat production is 1 µ

W/m3 and 3×e(z/10) μ W/m3 for the sediments and crust, respectively. Each basin is shown by a horizontal grey line indicating the average surface heat flow value and average sediment thickness at the calculated site (grey dot). The minimum to maximum sediment thickness in the basin is indicated with the grey line.

530 Based on the findings presented in Fig. 7, we have computed an initial estimate of the depth of the 150°C isotherm for the onshore basins presented in this study, where surface heat flow is known, following the published values from Fernàndez et al., (1998) and compiled in the International Heat Flow Commission (Fuchs et al., 2023). As for thermal conductivities, we have taken the average thermal conductivities values in Torne et al. (2023). For instance, considering the Ebro Basin and the Guadalquivir Basin as end-

535 members for relatively high and low average heat flow values, respectively 75 mW/m^2 and 62 mW/m^2, we observe that for a constant conductivity of 2.0 W/mK, the depth of the isotherm in the Ebro Basin is considerably shallower (ranging from 6 km with no sediments to 3.75 km for a sediment thickness of 3.75 km) compared to the Guadalquivir Basin. In the Guadalquivir Basin, for equivalent sediment thickness values, the isotherm depth fluctuates between 7.75 km and 4.50 km, respectively. This difference is

540 attributed to the higher average heat flow values observed in the Ebro Basin compared to the Guadalquivir Basin. Additionally, increases in thermal conductivity lead to a rise in the isotherm depth, shifting to 6 km and 4.6 km in the Ebro Basin and to 7.75 and 5.70 km in the Guadalquivir Basin. However, it is important to stress that in both basins the impact of increasing conductivity results in the isotherm being situated at a greater depth, with it being less sensitive to variations in sediment thickness; this is clear

545 when one compares panels A to D in Fig. 7. Such an observation generally confirms the impact of sediment thickness and thermal conductivity on the spatial distribution of the 150°C isotherm, with a heightened significance in areas characterized by lower heat flow values.

5. Data availability

The SedDARE is available in the Spanish National Research Council repository, DIGITAL.CSIC
550 (https://doi.org/10.20350/digitalCSIC/16277) (Torne et al., 2024). A detailed list of the datasets can be found in Table S1.

6. Conclusions

Analyzing sediments is crucial for understanding a region's geological history, subsurface structure, and potential resources. The thickness and properties of sediment layers play a crucial role in subsurface
555 exploration, providing valuable insights for building more accurate geophysical models. Additionally, studying sediment properties is essential for assessing and mitigating geohazards, and informing

infrastructure planning and engineering. In summary, curating sediment data is essential for advancing knowledge and sustainable management of resources, protecting the environment, and making informed decisions across various scientific, economic, and social domains.

560 SedDARE-IB database has been created to facilitate the reuse and preservation of existing data by future generations of geoscientists. It achieves this by hosting sediment data in the online institutional repository DIGITAL.CSIC (Torne et al., 2024). The database accomplishes the international mandates of open-access data and the FAIR principles of data management. The database is a result of close collaboration between Portuguese and Spanish research teams, aiming to make available sediment data of the Iberian

565 Peninsula easily accessible. Presently, SedDARE contains 29 datasets of isobath maps depicting the Top of Basement and base of Cenozoic stratigraphic markers of the Iberian Peninsula and its surrounding margins.

As an example of the use of the data set, we conducted a systematic thermal analysis examining the influence of the sediment thickness on the depth location of the 150ºC isotherm. The obtained results

570 indicate a complex relationship between isotherm depth and sediment thickness. While an increase in sediment thickness initially results in higher temperatures at relatively shallow depths, there is a critical threshold value in sediment thickness beyond which the 150ºC isotherm stabilizes at a constant depth. Moreover, an increase in thermal conductivity correlates with a deepening of the 150ºC isotherm, while an increase in heat flow leads to the opposite effect.

575 When comparing the Ebro and the Guadalquivir basins as end-members of basins with relatively high and low average heat flow values (75 mW/m² and 62 mW/m², respectively), one records differences in the depth of the 150ºC isotherm between 1 and 1.5 km. The trend is one of a deeper 150ºC isotherm whenever a relatively higher thermal conductivity is recorded.

The spatial distribution of the 150ºC isotherm is notably affected by variations in thermal conductivity,

580 with a heightened significance in those basins characterized by lower heat flow values. Here, the impact of thermal conductivity is particularly pronounced, influencing the isotherm depth to a greater extent than variations in sediment thickness.

Author contributions

MT, IJ-M, AG, TA, JC and ER conceived the idea. MT, CA, HH, AB worked on the data curation and

585 collation of the datasets of the Iberia Alpine foreland basins (JLGL, CA, MT, AB) and Western Mediterranean basins (HH, MT). TS, JC, ER, HM worked on the data curation and collation of the datasets

of the deep offshore Atlantic Margin, Alentejo and Algarve basins. IJ-M and MT conducted the thermal calculations. JC, JV, TA, HH, and ER prepared the geological section of the paper. MT and AB managed the uploading of datasets into DIGITAL.CSIC. MT prepared the original manuscript; all authors

590 contributed to the review and editing. TA handled English editing of the manuscript.

Competing interests

The contact author has declared that none of the authors has any competing interests.

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Acknowledgments

This work has been performed using the facilities of the Laboratory of Geodynamic Modeling from Geo3BCN-CSIC. Figures 1 to 7 were totally or partly drawn using GMT software (Wessel et al., 2019).

605 The authors thank xxxx anonymous reviewers for their comments and suggestions that have improved the previous version of this manuscript. TGS is acknowledged for the provision of seismic data on the entire Atlantic Margin of Iberia.

Financial support

This research has been partly supported by the project funded by the Spanish Government GeoCAM

610 (PID2022-139943NB-I00) and GEOADRIA (PID2022-139943NB-I00). The onshore Iberia data sets were compiled under the umbrella of the ALGECO2 project (IGME-CSIC). The Lower Tagus Basin and Alentejo datasets were prepared by JC under the scope of academic thesis and updated during projects SISMOD/LISMOT-Finite Seismic Source Modeling by Joint Inversion of Seismic and Geodesic Data and Strong Ground motion in the Lower Tagus Valley" (PTDC/CTE-GIN/82704/2006) and NEFITAG-Strong

615   Ground Motion and Near Field Effects in the Lower Tagus Region" (PTDC/CTE-GIX/102245/2008),
financed by the Portuguese Foundation for Science and Technology. AMGG received a grant (FJC2021-
047434-I)   funded   by   MICIU/AEI   /10.13039/501100011033   and   by   "European   Union
NextGenerationEU/PRTR".

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