BSGF - Earth Sciences Bulletin 2020, 191, 22
© J. Miró *et al.*, Published by EDP Sciences 2020
https://doi.org/10.1051/bsgf/2020024

Special Issue Orogen lifecycle: learnings and perspectives from Pyrenees, Western Mediterranean and analogues, ed. O. Lacombe, S. Tavani, A. Teixell, D. Pedreira and S. Calassou (Guest editors).

BSGF Earth Sciences Bulletin

Available online at:
www.bsgf.fr

OPEN ACCESS

The Basque – Cantabrian Pyrenees: report of data analysis

Jordi Miró[1,2,*], Josep A. Muñoz[2], Gianreto Manatschal[1] and Eduard Roca[2]

[1] Institut de Physique du Globe de Strasbourg, CNRS-UMR 7516, EOST, Université de Strasbourg, 1, rue Blessig, F67084 Strasbourg Cedex, France

[2] Institut de Recerca Geomodels, Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Universitat de Barcelona, Barcelona 08028, Spain

Received: 18 February 2020 / Accepted: 22 June 2020 / Published online: 11 December 2020

Abstract – This contribution presents the analysis of a data set that was put together in the PhD thesis of Jordi Miró which is part of the OROGEN Project. The Basque – Cantabrian Pyrenees, that are the focus of this report, have been extensively studied over the last years. Several open debates in the Earth Science community aroused from this realm regarding the formation and reactivation of rift domains and formation of fold and thrust belts. This report summarizes the main tectonic models proposed to explain both the extension and reactivation history over this area and compile a series of data to consider for further discussions and interpretations. This report includes a thematic map of the Basque – Cantabrian Pyrenees showing an analysis of the tectono-stratigraphic evolution of the area. The map covers an area of more than 33 000 km^2 and is a graphic representation of the geology of the region based on a large geodatabase including previous published maps and field observations. A composite reflection seismic line crossing the entire Basque – Cantabrian Pyrenees from the Ebro foreland basin to the offshore Landes High is also presented. This section enables to present a continuous dataset along the entire area with the projection of few drill holes, which are presented with the stratigraphic logs following the same tectono-stratigraphic legend obtained from the previous analysis. The main goal of this data report is to provide a coherent and complete dataset to the community, which enables to propose, discuss and test some of the new concepts related to the formation and reactivation of rifted margins. This data report is complementary to the contributions of Lescoutre and Manatschal (2020) and Cadenas *et al.* (in prep) that are part of the same special volume.

Keywords: Basque – Cantabrian Pyrenees / tectono-stratigraphy / seismic data / drill hole data

Résumé – Les Pyrénées Basco – Cantabriques : rapport d'analyse des données. Cette contribution présente l'analyse d'une compilation de données acquises par Jordi Miró lors de sa thèse de doctorat qui s'inscrit dans le projet OROGEN. Les Pyrénées Basco-Cantabriques, qui sont l'objet de ce rapport, ont été largement étudiées au cours de ces dernières années. Cette chaîne orogénique a alimenté de nombreuses discussions concernant la formation et la réactivation des domaines de rift ainsi que la formation des chaînes d'avant-pays (« fold-and-thrust belt »). Ce rapport résume les principaux modèles proposés dans la zone d'étude pour expliquer l'évolution tectonique de l'extension à la réactivation, et compile une série de données à prendre en considération pour les discussions et interprétations futures. Il comprend notamment une carte thématique des Pyrénées Basco-Cantabriques montrant les différentes unités tectono-stratigraphiques de la zone. La carte, qui couvre une superficie de plus de 33 000 km^2, est une représentation graphique de la géologie régionale s'appuyant sur une large quantité de données comprenant des cartes publiées précédemment ainsi que de nouvelles observations de terrain. Un profile de réflexion sismique composite traversant la totalité des Pyrénées Basco-Cantabriques (du bassin d'avant-pays de l'Ebre au Haut des Landes) est également présentée. Cette section permet de présenter un ensemble de données continu sur toute la zone *via* notamment la projection des informations extraites des puits de forage tels que les logs stratigraphiques. L'objectif principal de ce rapport est de fournir à la communauté

*Corresponding author: jmiropadrisa@unistra.fr

scientifique un ensemble de données cohérent et complet permettant de proposer, discuter et tester certains des nouveaux concepts liés à la formation et à la réactivation des marges hyper-étirées. Ce rapport de données fournit des informations complémentaires aux études disponibles dans cette publication spéciale du projet OROGEN.

Mots clés : Pyrénées Basque – Cantabriques / tectono-stratigraphie / sismique de réflexion / données de forage

1 Introduction

This report presents the analysis of a data set used in the PhD thesis of J. Miró to propose and test new extensional concepts for the Basque – Cantabrian Pyrenees [*e.g.* multistage and polyphase (Péron-Pinvidic and Manatschal, 2009)] and their role on the subsequent inversion of these basins. This report is part of a PhD that is in the framework of the OROGEN Project (www.orogen-project.com). The aim of the OROGEN Project is to make all data sets used and produced available for the community, the reason why this report is part of this special volume.

Datasets are fundamental to propose, discuss, improve, and test new tectonic concepts and models. In the case of the Basque – Cantabrian Pyrenees, many datasets have been published during the last decades supporting the most recent interpretations. These datasets include: magnetic data (Pedreira *et al.*, 2007); gravity data (Pedrera *et al.*, 2017; García-Senz *et al.*, 2019); velocity models (Pedreira *et al.*, 2003); seismic refraction (Ruiz *et al.*, 2017); thermochronology data (Fillon *et al.*, 2016), and magnetic susceptibility data (Soto *et al.*, 2007; Soto *et al.*, 2008). Some studies using reflection seismic data have been published recently (*e.g.* Carola *et al.*, 2015; Pedrera *et al.*, 2017) but a continuous seismic line crossing the entire Basque – Cantabrian Pyrenees has not been assembled and published yet. In this report we present a composite reflection seismic line crossing the whole Basque – Cantabrian Pyrenees from the Ebro Basin in the south to the offshore Landes High in the north. This composite line combined with available drill hole data from the area and tomographic data provides a dataset that forms the foundation for new interpretations and models of the area as well as for their calibration. To localize and help the understanding of the data presented (*i.e.* seismic lines and drill holes) a thematic map of the Basque – Cantabrian Pyrenees has been compiled based on the revision of previous geological maps, as well as field observations. The aim is to analyse the tectono-sedimentary evolution of the area in order to propose a new, simple and clear legend to understand the tectono-stratigraphic evolution of the area. Although this map is mainly built on existing data and does not pretend to be new, the compilation as presented in the map defines and describes the distribution of tectono-stratigraphic units in a new way and forms the foundation to support a new set of models and ideas presented in this volume and other upcoming publications.

The Pyrenees, geologically speaking, constitute the westernmost branch of the Alpine orogenic system that connects from the Pyrenees through the Alps and the Carpathians to the Himalayas (Carola, 2014). Within the Pyrenees, the stratigraphic record and the structural style changes significantly along strike (Carola *et al.*, 2013) and as a result, different physiographic units can be identified along the mountain belt. This fact has been captured in the literature with a wide range of names, both geographical and geological, being used to refer to the same areas (Fig. 1) (see Barnolas and Pujalte, 2004 for an extended revision of terminology). In this work, the area located between the Pamplona System [(Lescoutre and Manatschal 2020 (in this volume)] to the east and the Asturian Massif (also referred to as Cantabrian Mountains) to the west, will be named as the Basque – Cantabrian Pyrenees (Fig. 1). The traditional term Basque – Cantabrian Basin will be used to refer to the Mesozoic extensional basins that were formed between the Iberia, Ebro and Eurasian plate boundaries in this domain.

2 Geological framework

The Basque – Cantabrian Pyrenees are part of the doubly verging Pyrenean Orogen, which resulted from the Late Cretaceous to Cenozoic collision between the Iberia and Eurasian plates (Puigdefàbregas *et al.*, 1992; Muñoz, 2002; Vergés *et al.*, 2002) (Fig. 2a). The Alpine orogeny inverted the Mesozoic basins developed in the Bay of Biscay– Pyrenean realm, where a segmented hyperextended system formed the limit between the Iberian and European plates during the Late Jurassic to the Early Cretaceous. The transtensional and extensional evolution led to extreme crustal thinning (< 10 km) and locally to mantle exhumation in some of those basins (*e.g.* Basque – Cantabrian Basin and Mauleón Basin), whereas the Bay of Biscay further to the west reached the formation of oceanic crust (Sibuet *et al.*, 2004; Tavani *et al.*, 2018). However, the so-called Basque – Cantabrian Basin comprises, in fact, up to three Mesozoic sub-basins (Fig. 2a): (1) the Basque Cantabrian Basin *sensu strictu*, a NW– SE elongated basin with a more than 12 km thick succession of Upper Jurassic to Cenomanian sediments forming, at present, the Bilbao Anticlinorium (Lotze, 1960; Brinkmann and Lögters, 1968; Pujalte *et al.*, 1989; García-Mondéjar *et al.*, 1996; Barnolas and Pujalte, 2004; García-Mondéjar *et al.*, 2005); (2) the Cabuerniga Basin, a triangular shape basin with at least 3 km of Upper Jurassic to Lower Cretaceous sediments located to the north-west of the Basque – Cantabrian Pyrenees (Pujalte, 1979, 1981; García-Mondéjar, 1982; Espina, 1994); and (3) the Polientes Basin, located to the south-west of the area with a sedimentary succession of more than 4 km of sediments, Upper Jurassic to Lower Cretaceous in age (Garcia de Cortazar and Pujalte, 1982; Pujalte, 1982; Espina, 1996). The formation and reactivation of the Basque – Cantabrian Basin is the subject of a long debate between different schools, as detailed below.

2.1 Extensional basin models proposed in the Basque – Cantabrian Pyrenees

Three main extensional rift basin models can be invoked to explain the formation of the North Iberian rift system: the classical low-β basin (*i.e.* North Sea– type basins), the strike-slip transtensional basin (*i.e.* San Andreas system) and the high-β basin model (*i.e.* hyperextended Iberian margin type system) (Fig. 2b).

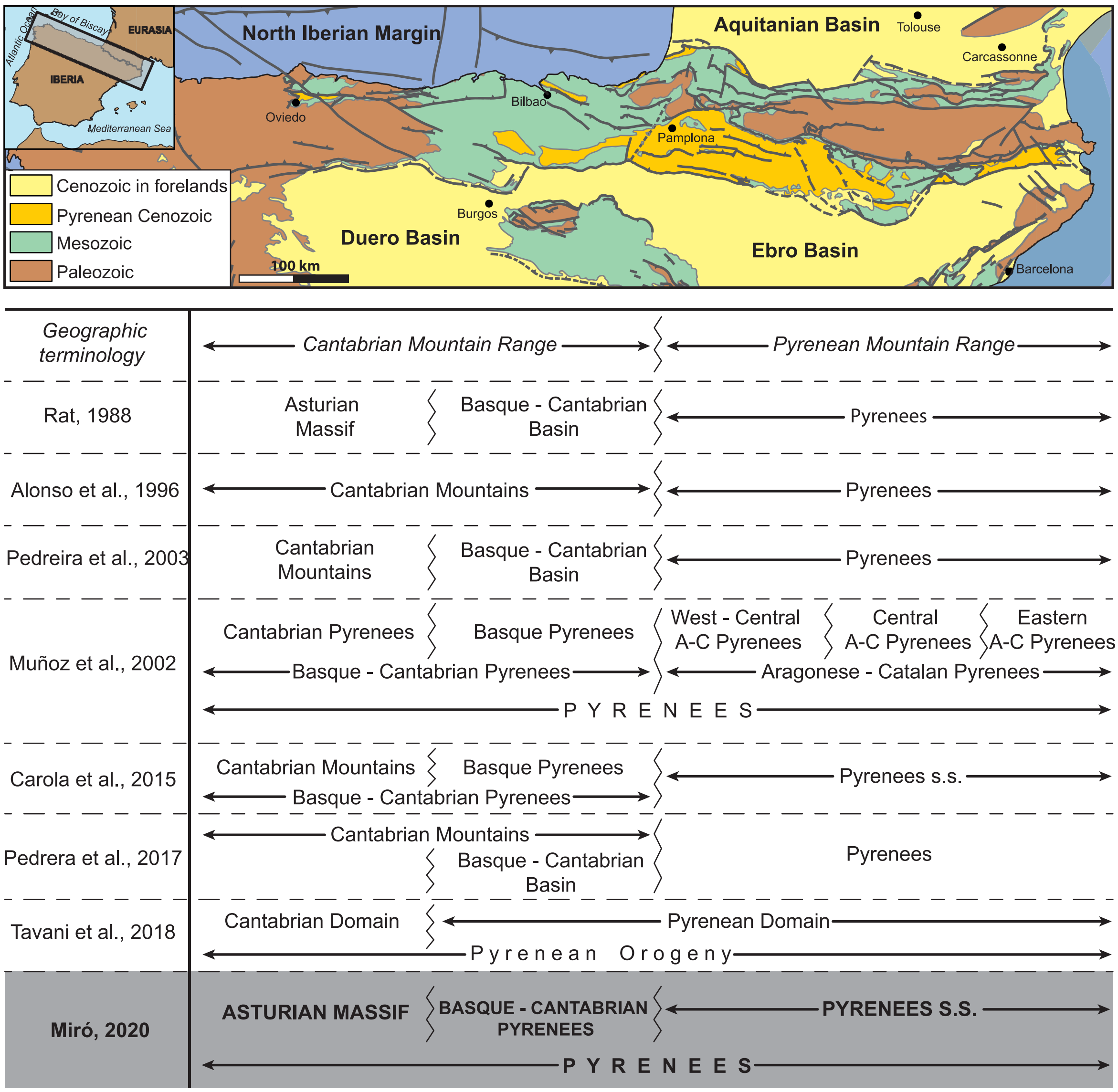

Fig. 1. Geographic terminology and some examples of geological terminology used in the Pyrenees. Modified from Barnolas and Pujalte (2004) and Carola *et al.* (2013).

In the Basque-Cantabrian Pyrenees all the previous models have been proposed to explain the formation and evolution of the extensional system. Quintana *et al.* (2015), Pedrera *et al.* (2017) and García-Senz *et al.* (2019) proposed that the basins were controlled by a main south-dipping normal fault located to the north. Consequently, they interpreted the Mesozoic succession in the Bilbao Anticlinorium area as the result of an extensional rollover related to the major fault. A second group of authors (*e.g.* García-Mondéjar, 1989; García-Mondéjar *et al.*, 1996, 2018) suggested a transtensional strike-slip model to explain the Mesozoic depocenter of the Basque–Cantabrian Basin. Moreover, Cámara (1997, 2017) introduced salt tectonics in the same kinematic model to explain the presence of diapirs and salt walls. The latter model proposed a sort of salt-controlled mini basins instead of basement-controlled half-graben basins. A third interpretation, inspired by the recent publications addressing the Newfoundland and West Iberia margins (Péron-Pinvidic and Manatschal, 2009) and the Arzacq-Mauleon Basin (Jammes *et al.*, 2009; Lagabrielle *et al.*, 2010), explains the Mesozoic evolution of the Bay of Biscay by a combination of the classical extensional model and the hyperextended model (Roca *et al.*, 2011). Following this interpretation, high-angle normal faults controlled the deformation in the brittle parts of the crust and mantle while deformation was distributed and decoupled in the ductile levels. In areas where crust was notably thinner due to high lithospheric extension, the basin structure was asymmetric and controlled by extensional detachment faults dipping to the north and cutting the entire residual < 10 km thick brittle crust (*e.g.* Basque–Cantabrian Basin).

2.2 Compressional models applied to the Basque–Cantabrian Pyrenees

For the subsequent reactivation of the depocenters located in the Basque–Cantabrian Basin, different models have been proposed, being grouped in: (1) thin-skinned models, (2)

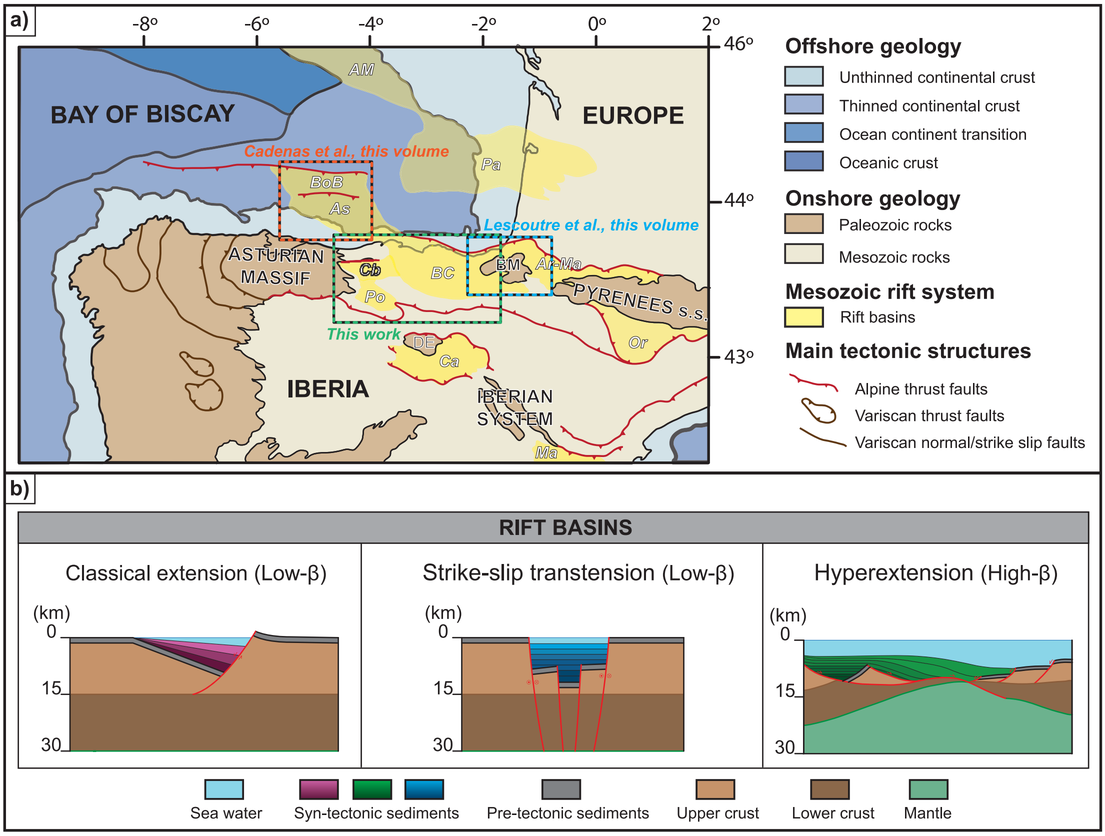

Fig. 2. A. Tectonic map of the Pyrenean– Bay of Biscay realm with the main structural features resulted from the Alpine orogeny and the presence of the main Mesozoic basins labelled in white: AM: Armorican Margin Basin, Ar-Ma: Arzaq-Mauleon Basin, As: Asturian Basin, BC: Basque – Cantabrian Basin s.s., BoB: Bay of Biscay Basin, Ca: Cameros Basin, Cb: Cabuerniga Basin, Po: Polientes Basin, Or: Organyà Bain, Ma: Maestrat Basin, Pa: Parentis Basin. Labelled in black Paleozoic Massifa: BM: Basque Massif, DE: Demanda Massif. Modified after Masini *et al.* (2014). B. Rift basin models described in the literature.

basement-involved thin-skinned models and (3) thick-skinned strike-slip models.

The first thin-skinned model (Hernaiz, 1994 and reference therein; Serrano *et al.*, 1994) was inspired on the south-western part of the Basque – Cantabrian Pyrenees related to the frontal imbricates (Folded Band) and the Burgalesa Platform (Fig. 3). This model argued for Jurassic to Lower Cretaceous sediments detached from the Paleozoic basement along the Triassic evaporites and transported several kilometres to the south. A more recent study proposed a thin-skin reactivation for the entire Basque – Cantabrian Basin, suggesting a large transport of the Mesozoic succession to the south on top of the Upper Triassic evaporites (Muñoz, 2019).

The second group of models assumed the involvement of the basement even in the frontal imbricates. Some authors argued for relatively thin basement thrust sheets, suggesting a basement-involved thin-skinned deformation (Espina, 1996; Quintana *et al.*, 2015). These authors recognized the presence of Triassic evaporites, which formed salt accumulations, such as diapirs, and acting as a partial decoupling horizon. Opposed to this interpretation, Pedrera *et al.*, 2017 and García-Senz *et al.*, 2019 suggested the classical thick-skinned deformation style, where thrusts are cutting the entire upper crust and some of them even the lower crust, implying a minor role of the salt during compressional reactivation. These models assumed that the compressional phase was controlled by the reactivation of inherited extensional structures describing a complex set of basement blocks, defining the architecture observed on the sedimentary cover.

The third set of models explained the contractional evolution of the Basque – Cantabrian Pyrenees as a reactivation of the extensional faults bounding the half-grabens with a significant component of strike-slip deformation, either with an important role of the Upper Triassic salt (Tavani *et al.*, 2013; Cámara, 2017) or a minor influence of salt (García-Mondéjar *et al.*, 1996; García-Mondéjar *et al.*, 2018).

3 Data

The composite seismic line presented in this report includes nine seismic lines provided by the Spanish Geological Survey (IGME) (see Appendix 1 for details): BB-1, PR-42, PR-42-P, S-82-14, VA-4, BR-9, BR-61, BR85-25 and 615. They were acquired between the 70's and the 90's during different hydrocarbon exploration campaigns after the first oil discoveries in the Basque – Cantabrian Pyrenees, such as the Ayoluengo oil field in 1963. Nine drill holes drilled during the same period for hydrocarbon exploration purposes and also provided by IGME have been projected to the composite seismic line (see Appendix 2 for more information): Rojas NE-1, Navajo-1, Trespaderne-1, La Hoz-2, Zuazo-1, Ubidea-1, Arratia-1,

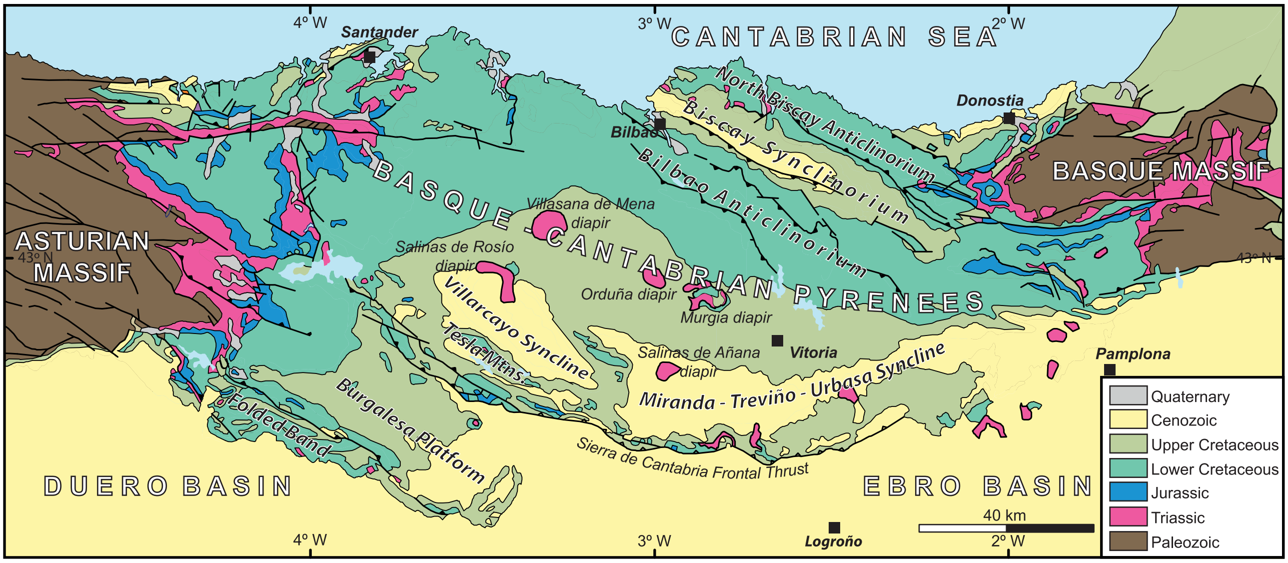

Fig. 3. Simplified geological map of the Basque – Cantabrian Pyrenees with the main domains labelled in capital letters and minor domains labelled in black. Modified after Ábalos *et al.* (2008).

Cormoran-1 and Vizcaya B-1. In order to project the boreholes that are in depth in a seismic line that is in time, a simple time-depth conversion to the seismic section has been done by using a generic velocity of 4800 m/s.

A compilation of several geological maps as well as maps from other thesis and publications have been compiled to present a new global thematic map of the entire Basque – Cantabrian Pyrenees (see Appendix 3 for the references of all the maps used). The simple but consistent organization of the units allows to document the tectono-stratigraphic evolution of the area from Triassic to present-day. The Figure 4 shows the polygons of the areas covered by the maps compiled in this report and the location of the drill hole data as well as seismic data presented.

4 Geological map of the Basque – Cantabrian region

The extensional models proposed to explain the formation of the Basque – Cantabrian Basin summarized above need to be further discussed in the light of the new ideas developed on the formation and evolution of rifted margins. Therefore, new thematic maps need to be developed analysing the tectono-stratigraphic sequences in order to accompany the new interpretations and concepts. Many studies in the literature have addressed and described the stratigraphy observed in the Basque – Cantabrian Pyrenees and the structures affecting the area (Triassic: García-Mondéjar *et al.*, 1986; Espina, 1997; Gómez *et al.*, 2007. Jurassic: Quesada *et al.*, 1991, 1993; Aurell *et al.*, 2003; Quesada *et al.*, 2005. Early Cretaceous: Pujalte, 1979, 1981, 1982; García-Mondéjar, 1989; García-Mondéjar *et al.*, 1996; Hernández *et al.*, 1999; Bodego *et al.*, 2015. Late Cretaceous: Pujalte *et al.*, 1989; Rodriguez-Lázaro *et al.*, 1998; Pujalte *et al.*, 2000; Castañares *et al.*, 2001; López-Horgue *et al.*, 2014. Cenozoic: Riba and Jurado, 1992; Quintà and Tavani, 2012, among many others) and the geological knowledge coming out has been captured in multiple geological maps (*e.g.* Carola *et al.*, 2015; Ábalos, 2016).

In this section, the tectonic evolution of the area and its stratigraphic response is summarized (Fig. 5). Therefore, a re-organization of units is proposed that reflects and allows to address further interpretations based on the recent developed concepts of rifted margins pointed out before (*i.e.* multistage and polyphase evolution). As a result, the thematic map presented in this work aims to be the basis for the upcoming studies addressing the formation and reactivation of the Basque – Cantabrian Pyrenees, as well as surrounding areas in the OROGEN project. Some of these interpretations that are based on the proposed legend of this report can be found in this volume [(Lescoutre and Manatschal, 2020 (in this volume) and Cadenas *et al.* (in this volume)] or they are related to ongoing investigations (Lescoutre, 2019). This map, therefore, represents a modification of existing maps combined with the revision of existing data sets as well as more than 1200 new field observations (*e.g.* dip-data measurements, lineation and contact observations).

The presented map (Appendix 4) is a graphic representation at 1:300 000 scale covering an area of 33 300 km^2 limited to the north by the Cantabrian Sea, to the south by the Ebro and Duero Tertiary Basins and to the east and west by Paleozoic massifs (Basque Massif and Asturian Massif, respectively). The organization of the legend has been defined based on the main tectonic phases recognized in the study area and its stratigraphic response (Fig. 5), as it is explained hereafter, rather than by geological ages (classical geological maps).

The oldest unit (*i.e.* basement, pre-rift 1) groups all the rocks from Paleozoic up to Permian. As the focus of the map is the Alpine cycle (*i.e.* Mesozoic to present-day), the previous events are not addressed in detail. The overlying Permo-Mesozoic to Cenozoic succession has been subdivided into syn-rift, post-rift and syn-compressional sequences, which can be further subdivided. The first sequence is the Lower Triassic extensional phase (*i.e.* Syn-rift 1), characterized by continental clastic sediments (Robles and Pujalte, 2004) and the late Triassic evaporites (*i.e.* Post-rift 1) (Serrano and Martínez del Olmo, 2004), which have been identified as a separate

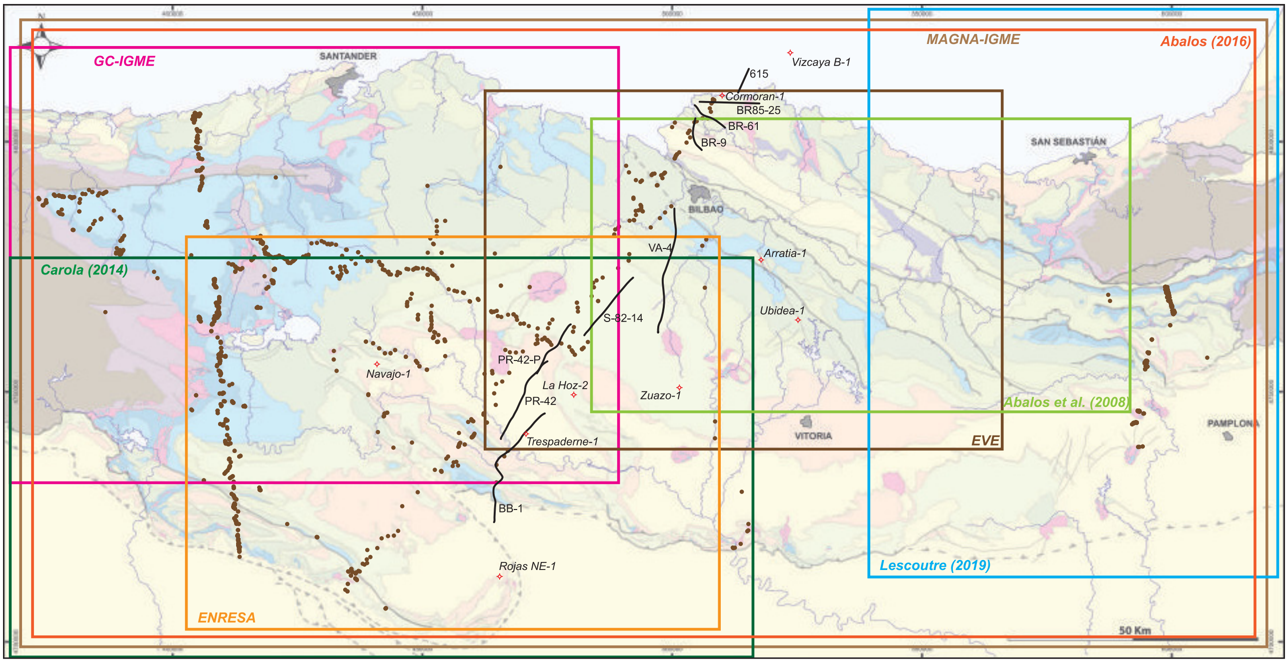

Fig. 4. Geological map of the Basque – Cantabrian Pyrenees with the location of seismic lines, drill holes, and field data (*i.e.* measurements and observations) in brown dots presented in this work. The geological maps compiled to build the thematic map presented in this work are also located: MAGNA-IGME: geological map at 1:50 000 scale from Instituto Geológico y Minero de España (IGME), GC-IGME: geological map at 1:25 000 scale from Gobierno de Cantabria and IGME, EVE: geological map at 1:25 000 scale from Ente Vasco de la Energia, ENRESA: geological map at 1:25 000 from Empresa Nacional de Residuos Radioactivos S.A., Ábalos (2016), Lescoutre (2019) and Carola (2014). See Appendix 3 for a detailed bibliography.

sequence due to its importance for the subsequent tectonic evolution. During Early to Middle Jurassic, a period of relative tectonic quiescence governed the northern Iberian domain (*i.e.* Post-rift 2). This phase is characterized by large carbonate platforms and marly successions defined as a unit itself in the map (Aurell *et al.*, 2003; Quesada *et al.*, 2005). The Late Jurassic to Barremian is characterized in the northern Iberian domain by a large-scale transtensional episode (Rat, 1988; Espina, 1994; Robles *et al.*, 1996), resulting in a syn-rift sequence localized in small, but kilometre-deep, depocenters (*i.e.* Syn-rift 2) (*e.g.* Asturian Basin, Cadenas *et al.*, 2018). The previous event contrasts with the next Aptian to Middle Cenomanian event that is linked to the major extensional phase structuring the Basque-Cantabrian Pyrenees. The sediments linked to the major extensional event were deposited leading to widely distributed depocenters that are either overlapping or forming away from the previous Late Jurassic to Barremian depocenters (Robles *et al.*, 1988; García-Mondéjar *et al.*, 1996; Lescoutre, 2019). The Aptian to Middle Albian extensional period is comprised in two units: the Aptian to Middle Albian succession (*i.e.* Syn-rift 3) and the Upper Albian to Middle Cenomanian (*i.e.* Syn-rift 4). The latter is unconformably overlying the previous sediments (Peropadre *et al.*, 2012) and it is related to a phase of mantle exhumation (Tugend *et al.*, 2014; Pedrera *et al.*, 2017). A post-rift (*i.e.* Post-rift 3) sequence recording thermal subsidence of Late Cenomanian to Early Santonian age is observed and manifested by shallow carbonate platforms established in the margins of the main depocenters, whereas a marly sedimentation was occurring basinwards (Floquet, 2004). Onset of convergence occurred at Middle Santonian time and coincided with a reestablishment of clastic sedimentation (*i.e.* Syn-compression 1). Finally, the Cenozoic period (*i.e.* Syn-compression 2) is known as the major compressional phase (mostly Eocene to Miocene) (Puigdefàbregas *et al.*, 1992; Pedrera *et al.*, 2017; Martín-Chivelet *et al.*, 2019).

5 Composite section across the Basque – Cantabrian Pyrenees

A SSW–NNE composite seismic section from the Ebro Basin in the south to the Landes High offshore in the north is presented in Figure 6. It provides a first order view of the architecture and nature of depocenters composing the Basque – Cantabrian Pyrenees on its central segment. Moreover, results of refraction seismic surveys (Fernández-Viejo *et al.*, 2000; Pedreira *et al.*, 2003; Ruiz *et al.*, 2017), and the source that is the origin of the gravimetric and magnetic anomalies (Pedreira *et al.*, 2007) have been projected in the section to have a complete crustal scale section crossing the entire Basque – Cantabrian Pyrenees.

In the section, the top basement interface corresponds to a major change in the reflectivity and can therefore be described as a main reflection across the composite line. The top basement is flat underneath the Duero Basin at about 3800 m depth, as confirmed by the drill hole Rojas NE-1 (Figs. 6 and 7), projected 12 km from the south. Beneath the Tesla Mountains and all along the imbricates related to the Sierra de Cantabrian Frontal Thrust, this interface appears slightly dipping to the north, being at 4000 m depth in the Navajo-1 drill hole (Figs. 6 and 7). The top basement keeps dipping to

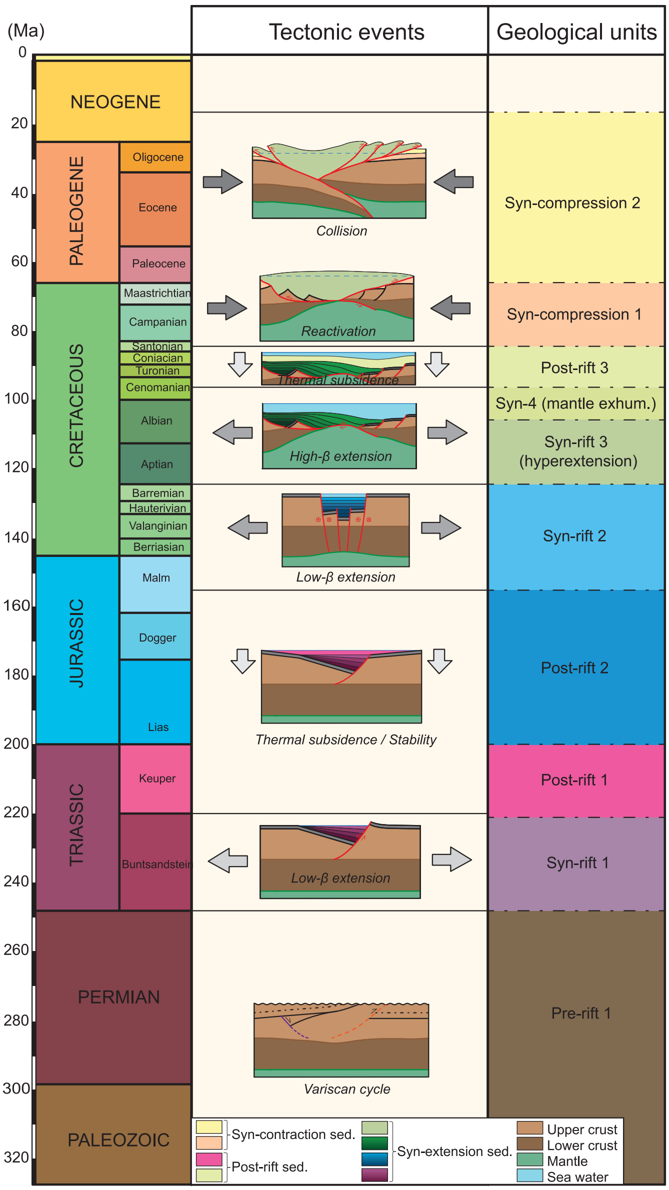

Fig. 5. Tectonic events documented in the Basque – Cantabrian Pyrenees from Paleozoic to present-day reported in the literature with the geological units grouped in this report.

the north about 5° degrees until the diapir alignment of Villasana de Mena – Orduña – Murgia, where the dip attitude changes, showing northward steeply dipping reflections. From that point to the north, the depocenter of the Basque-Cantabrian Basin *s.s.* thickens significantly, coinciding with the northward increase of the dipping of top basement. In the North Biscay Anticlinorium, top basement is flat and located at 4000 m, whereas at the shoreline, this contact is at 3300 m depth, as confirmed by the Cormoran-1 drill hole (Figs. 6 and 7). In the Landes High, top basement was drilled at 2800 m below sea level at the Biscaya B-1 well (Figs. 6 and 7).

In contrast to the top basement, the sedimentary cover is more deformed, which clearly argues for a strong decoupling between sediments and basement. Nevertheless, the sediments in the Ebro Basin are flat lying on top of the basement until the Sierra de Cantabria Frontal Thrust, where a panel of reflectors is dipping to the north representing the hanging wall of such frontal thrusts (Fig. 6). The Tesla Mountains area is deformed by thrusts and related folds and therefore the response in the seismic line is not clear (Appendix 4 and Fig. 6). However, some folded reflectors resulting from the compressional reactivation can be identified. As exposed at surface (Appendix 4), the complete stratigraphic succession in this area (*i.e.* Jurassic to Cenozoic) is thin and represented by few kilometres of sediments in total. To the north, a gentle syncline (*i.e.* Villarcayo Syncline) is recognized and made of a thick syn-compressional sedimentary pile as evidenced by the Trespaderne-1 well that drilled more than 2000 m of Late Cretaceous to Cenozoic sediments in its core (Figs. 6 and 7). The northern limb of the Villarcayo Syncline is conditioned by salt structures, such as the Salinas de Rosio– Salinas de Añana salt diapirs, which are the surface expression of a salt inflated area all along the northern limb of this syncline (Appendix 4). This is supported by the La Hoz-2 drill hole, which penetrates more than 1500 m of continuous evaporites (Fig. 7). Immediately to the north, the reflectors of a thick Mesozoic succession are dipping to the south on top of the north dipping basement. This tilted panel defines the southern limb of the Bilbao Anticlinorium (Appendix 4 and Fig. 6). The surface geology as well as the Ubidea-1 and Arratia-1 drill holes show a thick sedimentary cover of Late Jurassic to Middle Albian sediments forming the Bilbao Anticlinorium (Appendix 4 and Figs. 6 and 7). North of it, the quality of the seismic lines is not as good as further south due to the intense deformation in the area. However, some reflectors are showing the northern limb of the Biscay Sinclinorium and some sub-horizontal trends in the northern Biscay anticlinorium area are observed (Fig. 6). Finally, close to the shoreline, the presence of more recent seismic lines and the Cormoran-1 drill hole reflects a still deformed sedimentary cover by presenting some repetitions of the stratigraphy on top of Paleozoic basement (Fig. 7). The Biscay B-1 drill hole penetrated a thick and flat non deformed Late Cretaceous to Tertiary succession deposited on top of a thin Late Albian to Middle Cenomanian sequence, which is directly on top of the basement at 2800 m in the Landes High (Figs. 6 and 7).

From a crustal perspective, a normal, about 30 km thick Iberian crust is observed to the south beneath the Duero Basin but slightly tilted to the north underneath the frontal thrust and southern Basque – Cantabrian Pyrenees. A constant trend is observed until the northern edge of the Alavesa Platform, where the top basement increases the northward tilting as mentioned above, whereas the base of the crust follows a similar tendency slightly dipping to the north, suggesting a crustal thinning underneath the Bilbao Anticlinorium. However, in the same position, but at shallower level, a high magnetic and gravimetric anomaly is reported (Pedreira *et al.*, 2007). From that anomaly to the north, the European crust is present with a Moho depicted at around 30 km whereas the top basement remains at deeper levels as the thick sediments reported in the Bilbao anticlinorium are on top. Therefore, a thin European crust is assumed to the south whereas to the north its thickness increases up to a normal, about 30 km thick crust beneath the Cormoran-1 and Viscaya B-1 boreholes (Fig. 6). Geological cross sections partially based on the previous observations have been published (Muñoz, 2019)

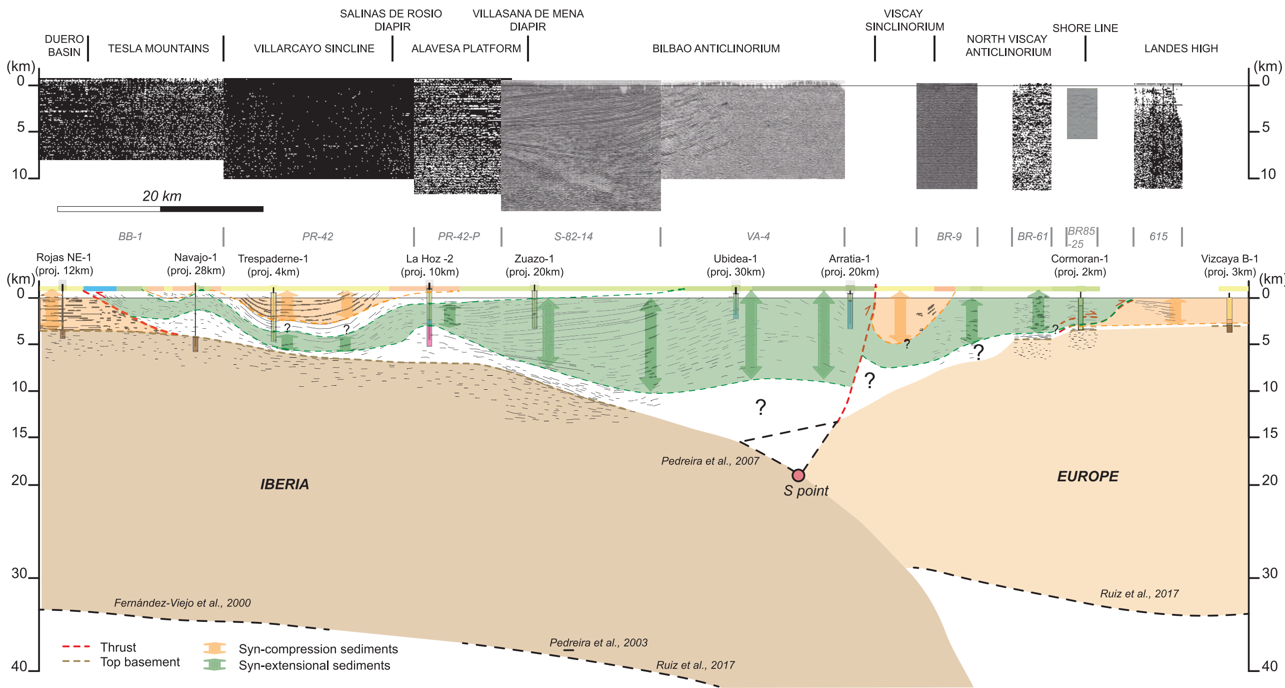

Fig. 6. Composite reflexion seismic line and its line drawing crossing the Basque – Cantabrian Pyrenees from south (left) to north (right) with nine boreholes and refraction seismic data projected. The surface geology and the main sedimentary successions of syn-extensional sediments and syn-compressional sediments are showed together with the main structures of the area. See the text and Appendix 1 for further details.

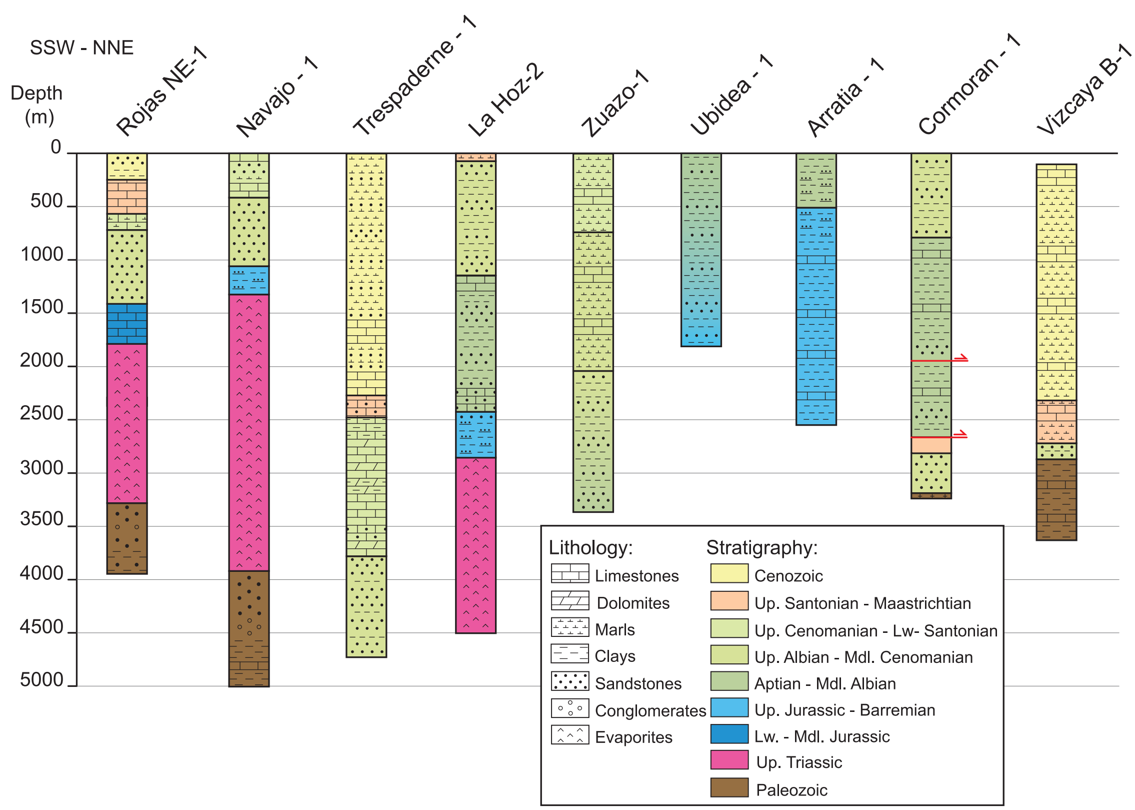

Fig. 7. Stratigraphic logs of nine drill holes from the Basque – Cantabrian Pyrenees. All of them start in the same reference level (0 meters) even if they are located at different topographic elevations. The vertical axis shows depth in meters. See Appendix 2 for further details of each drill hole.

suggesting an interpretation of the Basque – Cantabrian Pyrenees with a strong decoupling between basement and sedimentary cover.

6 Summary

The goal of this data report is to compile and present an analysis of a data set consisting of a composite seismic line crossing the Basque – Cantabrian Pyrenees with nine drill holes projected into the seismic transect. A new thematic map of the Basque – Cantabrian Pyrenees at 1:300 000 scale is also provided to better understand the tectonostratigraphic evolution of the area with a simple but robust organisation. This data is presented in order to provide the base for new interpretations on the formation and reactivation of the Basque – Cantabrian Pyrenees. Thus, this data report will be important and can be used to understand how the stacking of the different Mesozoic events recognized in the Basque – Cantabrian Pyrenees are organized and may built the foundation to test new concepts such as multistage and polyphase rift evolutions. Attempts to apply these concepts have been published already in examples presented in this volume.

Supplementary Material

Appendix 1. List of seismic lines, coordinates, and orientations. See InfoIGME (2020) for further details.
Appendix 2. List of drill holes with coordinates and measured depths. See InfoIGME (2020) for further details.
Appendix 3. References of all maps used to build the geological map presented.
Appendix 4. Geological map of the Basque – Cantabrian Pyrenees.

The Supplementary Material is available at http://www.bsgf.fr/10.1051/bsgf/2020024/olm.

Acknowledgements. This work represents the data-set that has been complied in the PhD of Jordi Miró and that belongs to the project CGL2017-85532-P of the Ministerio de Economía y Competitividad, the GEOMODELS Research Institute and the Grup de Geodinàmica i Anàlisi de Conques (2014SGR-467). We also thank reviewers Jesús Garcia-Senz and Ruth Soto and editors Olivier Lacombe and Stefano Tavani for helping to improve an earlier version of the report. The Instituto Geologico y Minero de España (I.G.M.E.) is thanked for providing seismic sections and well logs and Midland Valley for providing the academic license of the used Move software.

References

Ábalos B. 2016. Geologic map of the Basque-Cantabrian Basin and a new tectonic interpretation of the Basque Arc. *International Journal of Earth Sciences* 105(8): 2327–2354. https://doi.org/10.1007/s00531-016-1291-6.

Ábalos B, Alkorta A, Iríbar V. 2008. Geological and isotopic constraints on the structure of the Bilbao anticlinorium (Basque-Cantabrian basin, North Spain). *Journal of Structural Geology* 30: 1354–1367. https://doi.org/10.1016/j.jsg.2008.07.008.

Aurell M, Robles S, Bádenas B, Rosales I, Quesada S, Meléndez G, *et al.* 2003. Transgressive-regressive cycles and Jurassic paleogeography of northeast Iberia. *Sedimentary Geology* 162(3-4): 239–271. https://doi.org/10.1016/S0037-0738(03)00154-4.

Barnolas A, Pujalte V. 2004. La Cordillera Pirenaica: Definición, límites y división. In: Vera JA, ed. *Geología de España*. Madrid: SGE-IGME, pp. 233–241.

Bodego A, Iriarte E, Agirrezabala LM, García-Mondéjar J, López-Horgue MA. 2015. Synextensional mid-Cretaceous stratigraphic architecture of the eastern Basque-Cantabrian basin margin (western Pyrenees). *Cretaceous Research* 55: 229–261. https://doi.org/10.1016/j.cretres.2015.01.006.

Brinkmann R, Lögters H. 1968. Diapirs in western Pyrenees and foreland, Spain. Diapirism Diapirs, AAPG Spec Vol Tulsa, Oklahoma A153: 275–292.

Cadenas P, Fernández-Viejo G, Pulgar JA, Tugend J, Manatschal G, Minshull TA. 2018. Constraints Imposed by Rift Inheritance on the Compressional Reactivation of a Hyperextended Margin: Mapping Rift Domains in the North Iberian Margin and in the Cantabrian Mountains: Rift domains in the North Iberian margin. *Tectonics* 37 (3): 758–785. https://doi.org/10.1002/2016TC004454.

Cámara P. 1997. The Basque-Cantabrian basin's Mesozoic tectono-sedimentary evolution. *Mémoires de la Société Géologique de France* v. 171: 187–191.

Cámara P. 2017. Salt and Strike-Slip Tectonics as Main Drivers in the Structural Evolution of the Basque-Cantabrian Basin, Spain. In: *Permo-Triassic Salt Provinces of Europe, North Africa and the Atlantic Margins*. Elsevier, pp. 371–393. https://doi.org/10.1016/B978-0-12-809417-4.00018-5.

Carola E. 2014. The transition between thin-to-thick-skinned styles of deformation in the Western Pyrenean Belt. PhD thesis, University of Barcelona.

Carola E, Tavani S, Ferrer O, Granado P, Quintà A, Butillé M, *et al.* 2013. Along-strike extrusion at the transition between thin- and thick-skinned domains in the Pyrenean orogen (northern Spain). In Nemcok M, Mora AR, Cosgrove JW, eds. *Thick Skin-Dominated Orogens: From Initial Inversion To Full Accretion*. Geological Society of London Special Publications, London 377: 119–140. https://doi.org/10.1144/SP377.3.

Carola E, Muñoz JA, Roca E. 2015. The transition from thick-skinned to thin-skinned tectonics in the Basque-Cantabrian Pyrenees: the Burgalesa Platform and surroundings. *International Journal of Earth Sciences* 104(8): 2215–2239. https://doi.org/10.1007/s00531-015-1177-z.

Castañares LM, Robles S, Gimeno D, Vicente Bravo JC. 2001. The Submarine Volcanic System of the Errigoiti Formation (Albian-Santonian of the Basque-Cantabrian Basin, Northern Spain): Stratigraphic Framework, Facies, and Sequences. *Journal of Sedimentary Research* 71(2): 318–333. https://doi.org/10.1306/080700710318.

Espina RG. 1994. Mesozoic extension and Alpine compression in the western border of the Vasco-Cantabrian basin. *Cuad. Lab. Xeol. Laxe* 19: 137–150.

Espina RG. 1996. Tectónica extensional en el borde occidental de la Cuenca Vasco- Cantábrica (Cordillera Cantábrica, NO de España). *Geogaceta* 20(4): 890–892.

Espina R. 1997. La estructura y evolución tectonoestratigráfica del borde occidental de la Cuenca Vasco-Cantábrica (Cordillera Cantábrica, NO de España). Ph.D. Thesis (unpublished), Universidad de Oviedo, Oviedo, 230 p.

Fernández-Viejo G, Gallart J, Pulgar JA, Córdoba D, Dañobeitia JJ. 2000. Seismic signature of Variscan and Alpine tectonics in NW Iberia: Crustal structure of the Cantabrian Mountains and Duero basin. *Journal of Geophysical Research: Solid Earth* 105(B2): 3001–3018.

Fillon C, Pedreira D, Van der Beek PA, Huismans RS, Barbero L, Pulgar JA. 2016. Alpine exhumation of the central Cantabrian Mountains, Northwest Spain. *Tectonics* 35(2): 339–356. https://doi.org/10.1002/2015TC004050.

Floquet M. 2004. El Cretácico superior de la Cuenca Vasco-Cantábrica y áreas adyacentes. In: Vera JA, ed. *Geología de España*. Madrid: Sociedad Geológica de España – Instituto Geológico y Minero de España, pp. 299–306.

Garcia de Cortazar A, Pujalte V. 1982. Litoestratigrafía y facies del grupo Cabuérniga (Malm-Valanginiense Inferior?) al S de Cantabria – NE de Palencia. *Cuadernos Geología Ibérica* 8: 5–21.

García-Mondéjar J. 1982. Tectonica sinsedimentaria en el Aptiense y Albiense de la region Vascocantabrica occidental. *Cuadernos de Geologia Iberica* 8: 23–26.

García-Mondéjar J. 1989. Strike-slip Subsidence of the Basque-Cantabrian Basin of Northern Spain and its Relationship to Aptian-Albian Opening of Bay of Biscay. In Tankard AJ, Balkwill HR, eds. *Extensional Tectonics and Stratigraphy of the North Atlantic Margins*. *American Association of Petroleum Geologist*, Memoir 46: 395–409.

García-Mondéjar J, Pujalte V, Robles S. 1986. Caracteristicas sedimentologicas secuenciales y tectonoestratigraficas del triasico de la Cantabria y norte de Palencia. *Cuadernos de Geologia Iberica* 10: 151–172.

García-Mondéjar J, Agirrezabala LM, Aranburu A, Fernández-Mendiola PA, Gomez-Perez I, López-Horgue MA, *et al.* 1996. The Aptian–Albian tectonic pattern of the Basque Cantabrian Basin (Northern Spain). *Geological Journal* 31: 13–45.

García-Mondéjar J, López-Horgue MA, Aranburu A, Fernández-Mendiola PA. 2005. Pulsating subsidence during a rift episode: stratigraphic and tectonic consequences (Aptian-Albian, northern Spain). *Terra Nova* 17(6): 517–525. https://doi.org/10.1111/j.1365-3121.2005.00644.x.

García-Mondéjar J, Carracedo-Sánchez M, Owen HG, Fernández-Mendiola PA. 2018. The Early Aptian volcanic episode of Gutiolo (N Spain): Expression of the Bilbao Rift Fault Zone. *Geological Journal* 54(6): 3509–3526. https://doi.org/10.1002/gj.3342.

García-Senz J, Pedrera A, Ayala C, Ruiz-Constán A, Robador A, Rodríguez-Fernández LR. 2019. Inversion of the north Iberian hyperextended margin: the role of exhumed mantle indentation during continental collision. Geological Society, London, Special Publications, SP490-2019-112. https://doi.org/10.1144/SP490-2019-112.

Gómez JJ, Goy A, Barrón E. 2007. Events around the Triassic–Jurassic boundary in northern and eastern Spain: A review. *Palaeogeography, Palaeoclimatology, Palaeoecology* 244(1-4): 89–110. https://doi.org/10.1016/j.palaeo.2006.06.025.

Hernaiz PP. 1994. La Falla de Ubierna (margen SO de la cuenca Cantábrica). *Geogaceta* 16: 39–42.

Hernández JM, Pujalte V, Robles S, Martín-Closas C. 1999. División estratigráfica genética del grupo Campóo (Malm-Cretácico interior, SW cuenca Vascocantábrica). *Rev. Soc. Geol. España* 12(3-4): 377–396.

InfoIGME. 2020. Aplicación de consulta de información de hidrocarburos. Instituto Geológico y Minero de España. Available from http://info.igme.es/Hidrocarburos/ (Last consult: 2020/15/05).

Jammes S, Manatschal G, Lavier L, Masini E. 2009. Tectonosedimentary evolution related to extreme crustal thinning ahead of a propagating ocean: Example of the western Pyrenees. *Tectonics* 28 (4): 1–24. https://doi.org/10.1029/2008TC002406.

Lagabrielle Y, Labaume P, De Saint Blanquat M. 2010. Mantle exhumation, crustal denudation, and gravity tectonics during Cretaceous rifting in the Pyrenean realm (SW Europe): Insights from the geological setting of the lherzolite bodies. *Tectonics* 29: TC4012. https://doi.org/10.1029/2009TC002588.

Lescoutre R. 2019. Formation and reactivation of the Pyrenean-Cantabrian rift system: inheritance, segmentation and thermal evolution. PhD thesis, University of Strasbourg.

Lesoutre R, Manatschal G. 2020. Role of rift-inheritance and segmentation for orogenic evolution: example from the Pyrenean-Cantabrian system. *BSGF – Earth Sciences Bulletin* 0: 190086.

López-Horgue MA, Poyato-Ariza FJ, Cavin L, Bermudez-Rochas DD. 2014. Cenomanian transgression in the Basque-Cantabrian Basin (northern Spain) and associated faunal replacement. *Journal of Iberian Geology* 40(3): 489–506. https://doi.org/10.5209/rev_JIGE.2014.v40.n3.42819.

Lotze F. 1960. Zur Gliederung der Oberkreide in der Baskischen Depression (Nordspanien). *Neues Jahrbuch für Geologie und Paläontologie* 3: 132–144.

Martín-Chivelet J, Floquet M, García-Senz J, Callapez PM, López-Mir B, Muñoz JA, *et al.* 2019. Late Cretaceous Post-Rift to Convergence in Iberia. In: *The Geology of Iberia: A Geodynamic Approach*, Cham: Springer, pp. 285–376. https://doi.org/10.1007/978-3-030-11295-0_7.

Masini E, Manatschal G, Tugend J, Mohn G, Flament J-M. 2014. The tectono-sedimentary evolution of a hyper-extended rift basin: the example of the Arzacq-Mauléon rift system (Western Pyrenees, SW France). *International Journal of Earth Sciences* 103(6): 1569–1596. https://doi.org/10.1007/s00531-014-1023-8.

Muñoz JA. 2002. The Pyrenees. In: Gibbons W, Moreno T, eds. *The Geology of Spain*. Geological Society London, London, pp. 370–385.

Muñoz JA. 2019. Alpine Orogeny: Deformation and Structure in the Northern Iberian Margin (Pyrenees sl) C. In: Quesada C, Tomás Oliveira J, eds. *The Geology of Iberia: A Geodynamic Approach*. Cham: Springer, pp. 433–451.

Pedreira D, Pulgar JA, Gallart J, Díaz J. 2003. Seismic evidence of Alpine crustal thickening and wedging from the western Pyrenees to the Cantabrian Mountains (north Iberia). *Journal of Geophysical Research* 108: 2204. https://doi.org/10.1029/2001JB001667.

Pedreira D, Pulgar JA, Gallart J, Torné M. 2007. Three-dimensional gravity and magnetic modeling of crustal indentation and wedging in the western Pyrenees-Cantabrian Mountains. *Journal of Geophysical Research* 112: B12405. https://doi.org/10.1029/2007JB005021.

Pedrera A, García-Senz J, Ayala C, Ruiz-Constán A, Rodríguez-Fernández LR, Robador A, *et al.* 2017. Reconstruction of the exhumed mantle across the North Iberian Margin by crustal-scale 3-D gravity inversion and geological cross section. *Tectonics* 36 (12): 3155–3177. https://doi.org/10.1002/2017TC004716.

Péron-Pinvidic G, Manatschal G. 2009. The final rifting evolution at deep magma-poor passive margins from Iberia-Newfoundland: a new point of view. *International Journal of Earth Sciences* 98(7): 1581–1597. https://doi.org/10.1007/s00531-008-0337-9.

Peropadre C, Mediato JF, Hernaiz PP, Robador A, Solé FX, Sarrionandía F. 2012. La discordancia de La Mesa (base de las Facies Utrillas) en el sinclinal de Polientes (Cretácico, Cuenca Vasco-Cantábrica): implicaciones tectónicas. *Geotemas* 13: 85.

Puigdefàbregas C, Muñoz JA, Vergés J. 1992. Thrusting and foreland basin evolution in the Southern Pyrenees. In: McClay KR, ed. *Thrust Tectonics*, pp. 247–254. https://doi.org/10.1007/978-94-011-3066-0_22.

Pujalte V. 1979. Control tectónico de la sedimentación "purbeck-weald" en las provincias de Santander y N. de Burgos. *Acta Geológica Hispánica* 14: 216–222.

Pujalte V. 1981. Sedimentary succession and palaeoenvironments within fault-controlled basin: the "Wealden" of the Santander area, Northern Spain. *Sedimentary Geology* 28: 293–325.

Pujalte V. 1982. La evolución paleogeográfica de la cuenca "Wealdense" de Cantabria. *Cuadernos de Geología Ibérica* 8: 65–83.

Pujalte V, Robles S, Orue-etxebarría X, Zapata M, García-Portero J. 1989. Influencia del eustatismo y la tectónica en la génesis de secuencias y macrosecuencias deposicionales del Maastrichtiense superior-Eoceno inferior de la Cuenca Vasca. In: *Congreso Español de Sedimentologia, 12, Simposios*, pp. 147–156.

Pujalte V, Robles S, Orue-etxebarría X, Baceta JI, Payros A, Larruzea IF. 2000. Uppermost Cretaceous-Middle Eocene strata of the Basque-Cantabrian Region and Western Pyrenees: a sequence stratigraphic perspective. *Rev. Soc. Geol. España* 13(2): 191–211.

Quesada S, Robles S, Pujalte V. 1991. Correlación secuencial y sedimentológica entre registros de sondeos y series de superficie del Jurásico Marino de la Cuenca de Santander (Cantabria, Palencia y Burgos). Geogaceta 10: 3–6.

Quesada S, Robles S, Pujalte V. 1993. El Jurásico Marino del margen suroccidental de la Cuenca Vasco-Cantábrica y su relación con la exploración de hidrocarburos. *Geogaceta* 13: 92–96.

Quesada S, Robles S, Rosales I. 2005. Depositional architecture and transgressive-regressive cycles within Liassic backstepping carbonate ramps in the Basque–Cantabrian basin, northern Spain. *Journal of the Geological Society* 162(3): 531–548. https://doi.org/10.1144/0016-764903-041.

Quintà A, Tavani S. 2012. The foreland deformation in the south-western Basque-Cantabrian Belt (Spain). *Tectonophysics* 576-577: 4–19. https://doi.org/10.1016/j.tecto.2012.02.015.

Quintana L, Pulgar JA, Alonso JL. 2015. Displacement transfer from borders to interior of a plate: A crustal transect of Iberia. *Tectonophysics* 663: 378–398. https://doi.org/10.1016/j.tecto.2015.08.046.

Rat P. 1988. The Basque-Cantabrian Basin between the Iberian and European plates. Some facts but still many problems. *Revista de la Sociedad Geológica de España* 1: 327–348.

Riba O, Jurado MJ. 1992. Reflexiones sobre la geologia de la parte occidental de la Depresión del Ebro. *Acta Geológica Hispánica* 27: 177–193.

Robles S. 2004. El Pérmico de la Cuenca Vasco-Cantábrica. In: Vera JA, ed. *Geología de España*. Madrid: Sociedad Geológica de España – Instituto Geológico y Minero de España, pp. 269–271.

Robles S, Pujalte V. 2004. El Triásico de la Cordillera Cantábrica. In: Vera JA, ed. *Geología de España*. Madrid: Sociedad Geológica de España - Instituto Geológico y Minero de España, pp. 274–276.

Robles S, Pujalte V, García-Mondéjar J. 1988. Evolución de los sistemas sedimentarios del margen continental cantábrico durante el Albiense y Cenomaniense, en la transversal del litoral vizcaino. *Revista de la Sociedad Geológica de España* 1: 409–441.

Robles S, Pujalte V, Hernández JM, Quesada S. 1996. La sedimentación aluvio-lacustre de la Cuenca de Cirés (Jurásico sup.- Berriasiense de Cantabria) : un modelo evolutivo de las cuencas lacustres ligadas a la etapa temprana del rift noribérico. *Cuadernos de Geología Ibérica* 21: 253–275.

Roca E, Muñoz JA, Ferrer O, Ellouz N. 2011. The role of the Bay of Biscay Mesozoic extensional structure in the configuration of the Pyrenean orogen: Constraints from the MARCONI deep seismic reflection survey. *Tectonics* 30(2): TC2001. https://doi.org/10.1029/2010TC002735.

Rodriguez-Lázaro J, Pascual A, Elorza J. 1998. Cenomanian events in the deep western Basque Basin: the Leioa section. *Cretaceous Research* 19(6): 673–700.

Ruiz M, Díaz J, Pedreira D, Gallart J, Pulgar JA. 2017. Crustal structure of the North Iberian continental margin from seismic refraction/wide-angle reflection profiles. *Tectonophysics* 717: 65–82. https://doi.org/10.1016/j.tecto.2017.07.008.

Serrano A, Martínez del Olmo W. 2004. Estructuras diapíricas de la zona meridional de la Cuenca Vasco-Cantábrica. In: Vera JA, ed. *Geología de España*. Madrid: Sociedad Geológica de España – Instituto Geológico y Minero de España, pp. 334–338.

Serrano A, Hernaiz PP, Malagón J, Rodríguez Cañas C. 1994. Tectónica distensiva y halocinesis en el margen SO de la cuenca. *Geogaceta* 15: 131–134.

Sibuet J-C., Srivastava SP, Spakman W. 2004. Pyrenean orogeny and plate kinematics. *Journal of Geophysical Research* 109: B08104. https://doi.org/10.1029/2003JB002514.

Soto R, Casas-Sainz AM, Villalaín JJ, Oliva-Urcia B. 2007. Mesozoic extension in the Basque - Cantabrian basin (N Spain): Contributions from AMS and brittle mesostructures. *Tectonophysics* 445 (3-4): 373–394. https://doi.org/10.1016/j.tecto.2007.09.007.

Soto R, Casas-Sainz AM, Villalaín JJ, Gil-Imaz A, Fernández-González G, Del Río P, *et al.* 2008. Characterizing the Mesozoic extension direction in the northern Iberian plate margin by anisotropy of magnetic susceptibility (AMS). *Journal of the Geological Society* 165(6): 1007–1018. https://doi.org/10.1144/0016-76492007-163.

Sutra E, Manatschal G. 2012. How does the continental crust thin in a hyperextended rifted margin? Insights from the Iberia margin. *Geology* 40: 139–142. https://doi.org/10.1130/G32786.1.

Sutra E, Manatschal G, Mohn G, Unternehr P. 2013. Quantification and restoration of extensional deformation along the Western Iberia and Newfoundland rifted margins. *Geochemistry, Geophysics, Geosystems* 14: 2575–2597. https://doi.org/10.1002/ggge.20135.

Tavani S, Carola E, Granado P, Quintà A, Muñoz JA. 2013. Transpressive inversion of a Mesozoic extensional forced fold system with an intermediate décollement level in the Basque-Cantabrian Basin (Spain). *Tectonics* 32(2): 146–158. https://doi.org/10.1002/tect.20019.

Tavani S, Bertok C, Granado P, Piana F, Salas R, Vigna B, *et al.* 2018. The Iberia-Eurasia plate boundary east of the Pyrenees. *Earth-Science Reviews* 187: 314–337. https://doi.org/10.1016/j.earscirev.2018.10.008.

Tugend J, Manatschal G, Kusznir NJ, Masini E, Mohn G, Thinon I. 2014. Formation and deformation of hyperextended rift systems: Insights from rift domain mapping in the Bay of Biscay-Pyrenees. *Tectonics* 33(7): 1239–1276. https://doi.org/10.1002/2014TC003529.

Tugend J, Manatschal G, Kusznir NJ, Masini E. 2015. Characterizing and identifying structural domains at rifted continental margins: application to the Bay of Biscay margins and its Western Pyrenean fossil remnants. Geological Society, London, Special Publications 413(1): 171–203. https://doi.org/10.1144/SP413.3.

Vergés J, Fernàndez M, Martínez A. 2002. The Pyrenean orogen: pre-, syn-, and post-collisional evolution. *Journal of the Virtual Explorer* 8: 57–76. https://doi.org/10.3809/jvirtex.2002.00058.

Cite this article as: Miró J, Muñoz JA, Manatschal G, Roca E. 2020. The Basque – Cantabrian Pyrenees: report of data analysis, *BSGF - Earth Sciences Bulletin* 191: 22.