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# Evolution of the Pyrenees during the Variscan and Alpine Cycles 1: Variscan Cycle and Cretaceous Rifting

Nicolas Saspiturry, Jessica Uzel, Alexandre Ortiz

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SCIENCES

GEOSCIENCE

Dynamics of the Continental Lithosphere

**Evolution of the Pyrenees  
during the Variscan  
and Alpine Cycles 1**

*Variscan Cycle  
and Cretaceous Rifting*

**Coordinated by  
Nicolas Saspiturry  
Jessica Uzel  
Alexandre Ortiz**

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# Evolution of the Pyrenees during the Variscan and Alpine Cycles 1

SCIENCES

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# **Evolution of the Pyrenees during the Variscan and Alpine Cycles 1**

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# Preface

**Nicolas SASPITURRY<sup>1</sup>, Jessica UZEL<sup>2</sup> and Alexandre ORTIZ<sup>2</sup>**

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The Pyrenean Mountain belt is, without a doubt, one of the most emblematic of France's geological "objects". This mountain belt has long attracted many French and foreign scientists. Although its formation is relatively recent, the analysis of the innumerable variety of rocks composing it allows us to reconstitute the complex evolution of this area over the last 600 million years. The Pyrenees were studied extensively between 1960–1990 from a stratigraphic, sedimentological and tectonic point of view, through the realization of numerous PhD theses. The purpose of these theses was to produce the 1/50,000 scale geological maps published by the *Bureau de recherches géologiques et minières* (BRGM). The end of the geological BRGM mapping program caused geologists to lose interest in the Pyrenees in favor of the Alps. Indeed, the growth of knowledge concerning the formation of passive margins and sub-continental mantle exhumation at the ocean-continent transition has led many researchers to apply these concepts to the inverted Alpine passive margins, making them the emblematic fossil global standard for these objects. Nevertheless, the Pyrenees remain a first-class natural laboratory for better understanding of the Variscan and Alpine cycles.

Since the 2010s, Pyrenean research has experienced a significant boom, as evidenced by the many research projects that have emerged: (1) the ANR PYRAMID (2012–2016), (2) the Pyrenees project of the *Référentiel géologique de la France* (RGF) (2014–2019) and (3) the Convergence research program (2016–2020). The ANR PYRAMID, supported in part by the energy group TotalEnergies and BRGM, was entitled: "North PYREnees: Integrated assessment of fluid migration

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history, rift inversion, the role of surface processes and deformation in the evolution of an orogenic retrowedge and its foreland basin". The goals of this ANR grant were to (1) understand the overall 3D structural style and architecture of the North Pyrenean foreland system, and define the role of crustal inheritance within it; (2) link sediment transfer, landform formation and exhumation to the evolution of the foreland basin; and (3) quantify fluid-rock interactions from pre-orogenic extension to compression. Following the success of the ANR PYRAMID, BRGM has decided to continue by re-initiating scientific research on the Pyrenees.

Developed by BRGM, the RGF program, following the 1:50,000 geological map of France program, aimed to constitute the new foundation of French geological knowledge. Selected for their societal and academic attributes, the Pyrenees and their northern foreland constituted the first territory to apply the concepts of the RGF program. The RGF program consisted of reusing, reinterpreting and unifying different sources of surface and subsurface data on a single map, whether they came from geological maps, the subsurface data bank or oil and geothermal drilling. The objective of the RGF was, in the long term, the multi-scale representation of the geological knowledge of France in three dimensions, taking into account the physical properties of rocks. A true strategic project for BRGM and the entire scientific community, the RGF was part of a mission to support public policies by offering a response to the problems of land use planning, natural resource management and seismic and flood risk prevention. The RGF Pyrenees project, which lasted five years, revisited the 600 million years of geological history of this mountain belt. The goal of the RGF Pyrenees project was to (1) revisit the knowledge of the Paleozoic basement of the Pyrenees, exhumation and denudation during the tertiary orogeny and (2) constrain the processes of formation of the North Pyrenean rift and the exhumation of the continental mantle during the Lower Cretaceous, of which the lherzolites lining the belt are relics.

Finally, the Convergence research program (2016–2020) is the result of a close collaboration between TotalEnergies, BRGM and CNRS. This national research program aimed to structure research activities on mountain ranges and their adjacent sedimentary basins. This major scientific program included two projects: OROGEN and SOURCE TO SINK. The SOURCE TO SINK project was designed to better understand the processes of landform creation and erosion that lead to the formation of sedimentary basins from their source to the depositional zone. At a larger scale, OROGEN was an integrated holistic geosciences research project coordinated by INSU, with the objective of pushing back the limits of knowledge in terms of understanding the mechanisms behind mountain formation, as applied to the Pyrenean belt. The Pyrenees represented an exceptional study area due to its geological singularities: (1) the passive margins inherited from the Cretaceous

rifting partially preserved during continental subduction and then collision, and (2) the variation of its deformation states, between the Bay of Biscay and the Gulf of Lion, allowing us to study, in detail, how this domain evolves during compression and postorogenic phases. The presence of preserved basins of Cretaceous age, accessible from the outcrop in the north of the axial zone of the chain, has allowed for the acquisition of a unique data set for this type of domain, in particular the continental crust thermal evolution during the rifting stage.

The works of the SCIENCES series by ISTE and Wiley on the Pyrenees thus report on the evolution of geological knowledge, from the Variscan cycle to the Alpine cycle, resulting from these three major scientific research programs: the ANR PYRAMID, the RGF Pyrenees project and the Convergence research program. These publications logically involve many of the leading scientific actors of these research programs. We would like to thank the authors of the chapters who participated in the construction of these works. We would also like to thank Yves Lagabrielle and Sylvie Leroy for trusting us to manage this edition on Pyrenean geology.

August 2023