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Research paper

Characterization of the source rocks of a paleo-petroleum system (Cameros Basin) based on organic matter petrology and geochemical analyses

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ABSTRACT

The Cameros Basin is a paleo-petroleum system formed in the north-eastern Iberian Peninsula. The basin formed during the Mesozoic Iberian Rift and was later inverted during the Alpine orogeny. Hydrothermal events took place during the post-extensional and inversion stages, producing an important impact on the thermal history of the basin. In order to determine the source rock of the petroleum system of the basin, organic matter characteristics, the petroleum generation potential and the maturity of the basin infill are determined by means of petrology and geochemical analyses.

Several organic rich units of the stratigraphic record of the basin are potential source rocks for hydrocarbons generation, although their characteristics differ depending on their location. Organic matter content in the northern sector is scarce and limited to vitrinite, inertinite and solid bitumen particles. The residual total organic carbon (TOC < 1%), the low hydrocarbon potential (S2 < 0.3 mg HC/g rock, HI < 50 mg HC/g TOC), the mature to overmature thermal stages (%Ro from 1.7 to 4.6) and the presence of solid bitumen particles indicate that hydrocarbons have been already generated by these rocks. In contrast, the southern sector of the basin is characterized by abundant organic matter remnants (TOC from 2 to 17%) and immature to early oil-window thermal conditions (0.38–0.75%Ro), indicating a high hydrocarbon potential for these rocks (S2 from 11 to 123 mg HC/g and HI values from 23 to 715 mg HC/g TOC).

The different evolution of the source rocks in the basin is the result of the combination of differential subsidence rates, which determine different thermal histories and of the circulation of hydrothermal fluids in the northern-central sector during the evolution of the basin.

1. Introduction

Source-rock characterization is an important risk-reduction tool that is essential to ensure an effective search in oil and gas prospecting, especially in the case of basins with complex thermal evolutions and those affected by hydrothermalism (Tissot and Welte, 1984; Magoon and Dow, 1994). Source rock characterization includes the type and amount of organic matter contained in the rocks and their hydrocarbon generation potential. In the case of mature-to-overmature deposits, these data can be difficult to obtain.

This paper presents an interesting case-study that is not commonly reported in the literature: a paleo-petroleum system (the Cameros Basin petroleum system) where the original source rocks are currently in an overmature thermal stage. For this purpose, the petrographic and geochemical "signature" of a source rock that has already completely generated and expelled hydrocarbons is reconstructed. The knowledge obtained could provide the key to determining whether the exploitation of a petroleum system is feasible.

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Since the thirties it has been known that the Cameros Basin (north-eastern Spain) is a paleo-petroleum system, in spite of a small number of tar sandstone accumulations formed in the southern part of the basin (Fig. 1). However, due to the complex thermal history of the Cameros Basin, to date, no major effort has been performed to determine the elements and processes of the petroleum system of the basin (Magoon and Dow, 1994).

The Cameros Basin is an inverted extensional basin that is part of the intraplate Iberian Chain, which formed during the second stage of the Mesozoic Iberian rift (Late Jurassic-Early Cretaceous). During the extensional phase part of the basin was affected by a high rate of subsidence that allowed the basin infill to reach sufficiently high temperatures for hydrocarbon generation to take place (Omodeo Salé et al., 2015). Furthermore, several inorganic proxies (mineral paragenesis, illite crystallinity, fluid inclusions, etc.) indicate that the basin infill deposits have undergone a strong thermal alteration related to hydrothermal events that took place during the evolution of the basin (Casquet et al., 1992; Barrenechea et al., 1995, 2001; Alonso-Azcárate et al., 1999; Mata et al., 2001; Mantilla-Figueroa et al., 2002; Ochoa et al., 2007; Del Río et al., 2009; González-Acebrón et al., 2012).

This work aims to identify the potential source rocks in the Cameros Basin by analysing the petrographic and geochemical properties of the organic matter remnants and the products generated by pyrolysis. A detailed study of the organic matter of the basin has been performed in order to determine: 1) the amount and type of organic matter preserved in the basin; 2) the stage of thermal maturity of the basin infill; 3) the effect of the circulation of hydrothermal fluids upon the evolution of organic matter; 4) the past and present hydrocarbon potential of the identified source rocks.

2. Geological setting

The Cameros Basin (NE Spain) belongs to the northwestern Iberian Range, an intraplate compressional chain that extends from the eastern to the central and northern areas of the Iberian Peninsula (Fig. 1). The basin was formed as a consequence of the Mesozoic Iberian Rift, resultant of the opening of the Western Tethys and the North Atlantic domains (Arche and López-Gómez, 1996; Mas et al., 2003; Salas et al., 2001; Vera, 2001; Verges and García-Senz, 2001). The basin was inverted, during the Alpine orogeny (Eocene to Early Miocene), when the Iberian Chain was formed (Salas and Casas, 1993; Salas et al., 2001).

The basin substratum is composed of Triassic and Jurassic rocks, up to Tithonian in age, deposited during the first extensional and post-extensional stages of the Mesozoic Iberian Rifting (Mas et al., 1993; Salas et al., 2001) (Fig. 2). The substratum deposits, defined as "pre-extensional deposits", crop out along the entire northern border of the basin and part of the southern border where they are

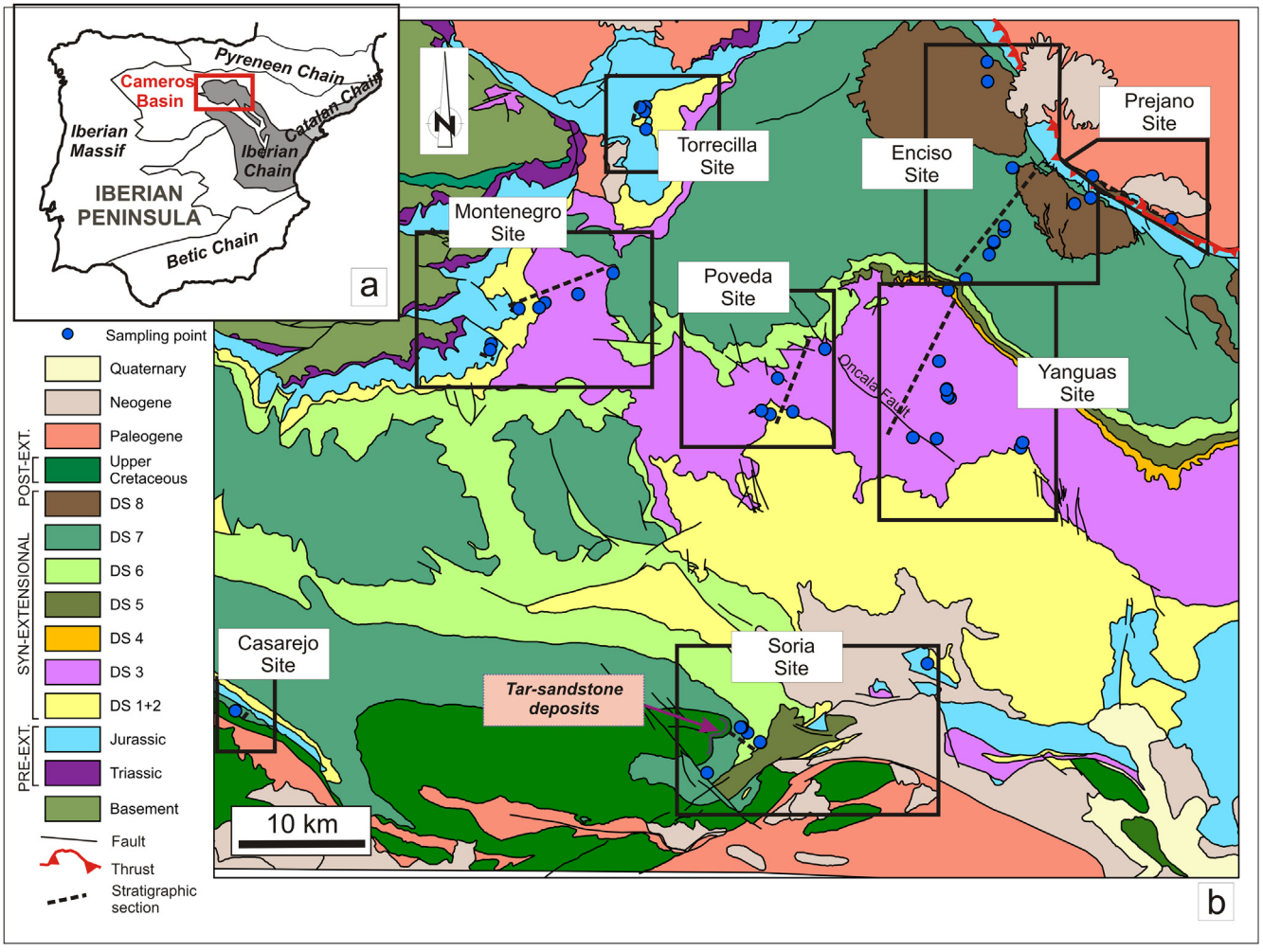

Fig. 1. **(a)** Location of the Cameros Basin in the geological context of the Iberian Peninsula; **(b)** Geological setting of the study area and location of the sampling points.