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The role of solid bitumen in the development of porosity in shale oil reservoir rocks of the Upper Cretaceous in Colombia

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ABSTRACT

The La Luna Formation (Turonian–Santonian age) has been traditionally considered as one of the main hydrocarbon source rocks in the Middle Magdalena Valley Basin (MMV) in Colombia. At present this formation is also considered as an organic matter-rich reservoir of shale oil type (unconventional petroleum system) of interest due to its significant resources of recoverable oil. Given the interest in this formation, and the need to increase the knowledge of its physico-chemical characteristics, a series of petrographic, geochemical (TOC content and Rock-Eval pyrolysis) and textural analyses (picnometry and mercury intrusion porosimetry, MIP) were carried out to investigate two of its members: Galembo and Salada that were sampled from a core well perforated at the center of the basin. The organic fraction of both members, Galembo and Salada, is made up mainly of a kerogen of Type II typical of a marine paleoenvironment, solid bitumen and hydrocarbons. The content in organic matter of terrestrial origin is very scarce-to-null. These rocks have a degree of maturity that corresponds to the oil window, and their high hydrogen content in combination with a relatively high carbon content makes them excellent source rocks. The uneven distribution of the various types of organic matter along the Galembo and Salada Members, particularly of the solid bitumen that is concentrated at the lower levels of both members has resulted in large variations in porosity, pore size distribution and modal pore throat characteristics even with small variations (centimetric) in depth. The sedimentary levels in which kerogen is the predominant type of organic matter have a pore size distribution in the range of mesopores and macropores of small size, whereas the solid bitumen-rich levels show a predominance of pores of small pore size with a modal pore throat diameter below 10 nm. The preliminary adsorption data obtained for all these samples (to be published in a study that will follow this), indicate that they contain some micropores, which is significant in the case of levels with a high content in solid bitumen.

1. Introduction

The La Luna Formation (Turonian–Santonian, Upper Cretaceous) has been traditionally considered as one of the main hydrocarbon source rocks in the Middle Magdalena Valley Basin (MMV) in Colombia. For this reason, several studies have been carried out on this formation in different parts of the basin in relation with its geology, hydrocarbon potential and geochemistry such as Morales et al. (1958); Zumberge (1984); Schamel (1991); Montgomery (1992); Rangel et al. (2000), and Marquez et al. (2014), among others. At present the La Luna Formation is also considered an organic matter-rich reservoir of the shale oil type (unconventional petroleum system) of interest due to its significant resources of recoverable oil (e.g., Juliao et al., 2013; Pérez et al., 2013; Rojas et al., 2013).

Given the widespread interest in this formation, and the need to broaden the knowledge of its physico-chemical characteristics, a series of petrographic, geochemical (TOC determinations and Rock-Eval pyrolysis) and textural analyses (picnometry and mercury intrusion porosimetry, MIP) were carried out to investigate two of their members: Salada and Galembo Members which are located at the lower and upper parts of the formation, respectively. Both members were sampled from a core well that was perforated at the center of the MMV basin (Fig. 1). The study of the porosity and pore size distribution of shale for gas and oil reservoir evaluation is important as they are key parameters, among others, for evaluating the quality of this type of rocks.

Therefore, the main objectives of this study were to determine the petrographic types of organic matter contained in the Salada and Galembo Members, their degree of maturity, hydrocarbon potential, together with its porosity and pore size distribution. From the results obtained these objectives were enlarged to determine the role of solid bitumen in the development of porosity in the different sedimentary levels of both members. Mercury injection porosimetry (MIP) analysis to obtain the pore volume for pore sizes between 5.5 and 12,000 nm is a conventional (this technique is normalized by ISO and ASTM

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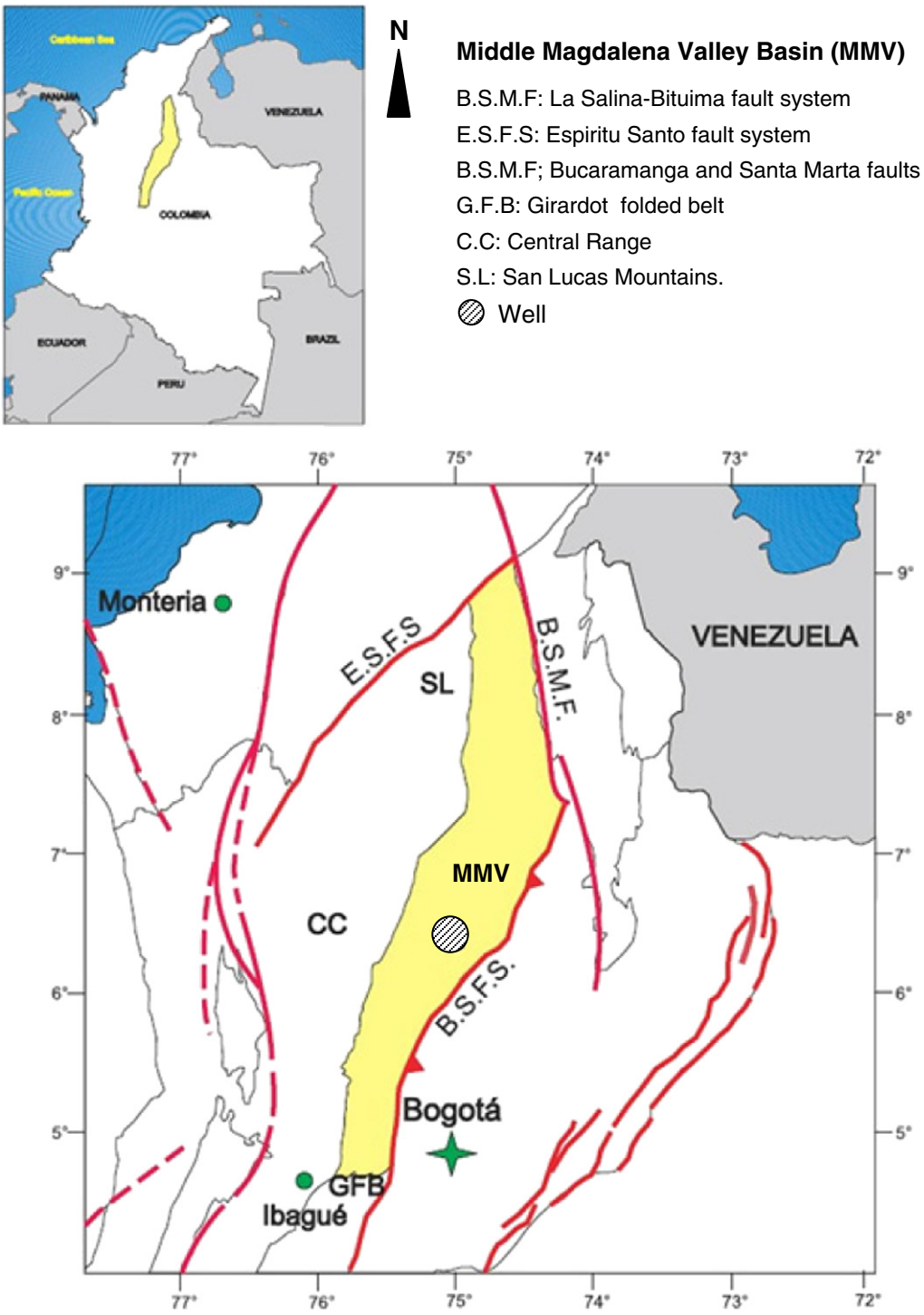

Fig. 1. Location map showing the Middle Magdalena Valley Basin (MMV) in Colombia (modified from Barrero 2007) and sampled site.

standards, see references), very well known and widely used method for determining porosity in porous materials (e.g., Alvarez et al., 1994; Ruiz et al., 1993, 2001, 2006; Girón et al., 2012; among other); in materials from various origins (e.g., Gil et al., 2013; Girón et al., 2012; Suárez-Ruiz and Parra, 2007 and references therein) in coals (e.g., Jiménez et al., 1998; Li et al., 1999; Okolo et al., 2015; Rubiera et al., 1999; Van Krevelen, 1993; Zhang et al., 2010), etc. In recent years mercury intrusion porosimetry have been applied to the study of porosity not only in coals but also in levels of shales (e.g., Al Hinai et al., 2014; Josh et al., 2012; Mastalerz et al., 2013; Ross and Bustin, 2009; Tian et al., 2013) containing dispersed organic matter.

If the various organic components (macerals) have different physico-chemical properties (as is reported in Taylor et al., 1998; Suárez-Ruiz and Crelling, 2008 from data of the ICCP) it can be assumed that not all types of organic matter behave in a similar way during mercury intrusion at high pressures, as will be shown below. A particular case is the type of organic matter known as solid bitumen. Solid bitumens as identified by optical microscopy using reflected white light