Petrological and Geochemical Study of the Organic Matter in the Sabinas-Piedras Negras Basin, Coahuila (NE Mexico)

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Abstract

This study presents a petrological and geochemical study of some source rocks in the Sabinas-Piedras Negras Basin, Coahuila (NE Mexico). The studied source rocks belong to Olmos (Late - Middle Maestrichtian), Eagle Ford (Late Cenomanian - Turonian), La Peña (Late Aptian), La Virgen (Late Hauterivian - Late Barremian), and La Casita (Kimmeridgian - Tithonian ) Formations. All the samples show type III organic matter predominance; type II organic matter being scarce. The reflectance varies in the samples in agreement with the maturation evolution (oil to gas window). Different phases of bitumen were observed in most samples and it could explain the variation of the geochemical parameters in the source rocks. The fracturing and porosity in the source rocks indicate the principal migration path of the hydrocarbons generated. La Casita Formation presented the best characteristics for hydrocarbon generation and storage. Finally, the thermal gradient variation in the source rocks was recorded by the vitrinite reflectance and it was reconstructed through distribution maps at different depths.

Keywords: Vitrinite reflectance, organic matter, petrography, thermal evolution

Introduction

The Sabinas-Piedras Negras Basin, Coahuila (NE Mexico; Figure 1) in the physiographic province called “Basin and Range” is constituted by a thick sedimentary succession disposed in synclines and anticlines, with a preferential direction NW-SE, formed during the Laramide Orogeny. This succession is a Jurassic to Cretaceous age (Eguiluz de Antuñano, 2001; Román-Ramos and Holguín-Quíñones, 2001). The sedimentary sequence is made up by silico-clastic, carbonate and evaporite rocks with a thickness of about 6 to 7 km (Eguiluz de Antuñano, 2001). The sequence shows the facies changes from East to West of the basin and the thickness variations of the formations. The geological history of NE Mexico is linked to the origin of the Gulf of Mexico as a result of the separation between the North American, African, and South American plates (Goldhammer and Johnson, 2001; Lawton et al., 2001). The separation of the plates caused the horst and graben formation in the studied region. The Sabinas-Piedras Negras Basin is mostly divided in two paleotectonic elements: Coahuila and Tamaulipas Peninsula. These geomorphological elements influenced in the deformation style of the Mesozoic and Tertiary sedimentary sequences. The Coahuila Peninsula and Coahuila Platform are defined as an extension southwards of the North American Continent during the Pre-Aptian epoch. In the region of Coahuila, the Tamaulipas Peninsula and Coahuila Platform embedded the physiographic province of “Basin and Range” to the N-E, and to the S, respectively. The studied region reflects the cushioning effect of the Coahuila Platform during the Laramide orogeny (Goldhammer and Johnson, 2001; Lawton et al., 2001).
Sampling

The sample selection was obtained from cuttings of old wells drilled in the studied region during the 1970s by the Exploration and Production Department of Mexican Petroleum (Petróleos Mexicanos, PEMEX), the national company of Mexico. The cuttings were controlled taking into account its lithological formation and depth. The samples are from Superior Jurassic to Tertiary age. The more important source rocks in the Sabinas-Piedras Negras Basin correspond to the following formations: Olmos (Superior Cretaceous), Eagle Ford (Superior Cretaceous), La Peña (Inferior Cretaceous), La Virgen (Inferior Cretaceous), and La Casita (Superior Jurassic). The samples of the Olmos Formation came from coal seams mined by Minerales Monclova, S.A. (MIMOSA, Cía.). On the other hand, PEMEX supplied the samples and some geochemical and petrographical data for fifty wells in the studied area. However, only a 20% of the data was considered reliable for study. Complementary geochemical and petrographical analyses were conducted.

Methodology

During the petrographical characterisation of the organic matter, the recent international classification of the vitrinite and inertinite groups were used. Vitrinite reflectance was carried out by using the method reported by Piedad-Sánchez et al. (2004) and Baker (1996). Birreflectance was performed on the bitumen to obtain the minimal and maximal vitrinite reflectance. Thus, the interpretation of gas formation, and of the bitumen and pyrobitumen deposition during the migration, was carried out by considering the secondary cracking. These observations were confirmed by fluorescence on the bitumen. Geochemical data of different wells in the Sabinas-Piedras Negras Basin, Coahuila, were used for comparison and interpretation, principally those derived from the chemical and Rock-Eval procedures.

Results

In this work, the Olmos Formation (Late and Middle Maestrichtian) shows a lithology made up by shales and sandstones with some intercalated coal seams. Vitrinite reflectance ranges from 0.7 to 1.2 % (mostly oil window) for the samples with a vitrinite predominance (Figure 2). The samples show considerable fracturing and numerous vacuoles traces of gas devolatilization. Inertinite is common and liptinite is always present but in small quantities (0-16 %). For the same samples, type III organic matter presents a typical maturation of oil window, but porosity is characteristic of gas windows.

The Eagle Ford Formation (Late Cenomanian - Turonian) presents a lithology essentially formed by limestones with fossiliferous shales. Under the microscope, the bitumen can be easily observed and differentiated in two families. Sometimes in the samples, some marks of oil impregnation was observed accompanied with a regular fracturing always filled with bitumen or/and pyrobitumen. The vitrinite content is scarce in the samples of the Eagle Ford Formation (Figure 3), and the vitrinite reflectance ranges from 0.67 to 1.29 % (oil to gas window). The inertinite and the bitumen are always present but the samples do not show the liptinite (namely, exudatinite). In this study the type III organic matter is dominant in the samples with small quantities of type II organic matter.

The La Peña Formation (Late Aptian) presents a lithology made up of limestone and fossiliferous shales. Under the microscope, the different types of texture of the pyrobitumen can be observed in the samples from the La Peña Formation. Moreover, some marks of oil impregnation can be found. The fracturing is frequent and filled with
pyrobitumen (Figure 4). The vitrinite reflectance ranges between 0.7 to 1.6 %, indicating the entry in the gas dry window of the studied samples of this formation. These samples present low vitrinite content and the presence of pyrobitumen in the fractures. The solid bitumen content accompanied by the inertinite is high. The samples show a predominance of type III organic matter and low content of type II organic matter.

La Virgen Formation (Late Hauterivian - Late Barremian) presents a lithology with evaporite and limestone predominance. The vitrinite is not very frequent and the fracturing observed is regular, sometimes it is filled with bitumen (Figure 5). Under the microscope, the migration pulses is supported by two phases of bitumen, and the devolatilization traces are present in some samples. The vitrinite reflectance in these samples ranges from 0.9 to 1.9 % (oil window to gas window transition). In the samples, despite the small quantity, vitrinite, inertinite and bitumen are easily identified. In the formation of these samples, liptinite is absent. In the samples studied, type III organic matter content is very high, while type II organic matter content is very low.

La Casita Formation (Kimmeridgian - Tithonian) is made up of the intercalation of shales, sandstones, and limestones. The samples exhibit different phases of bitumen under the microscope. Oil and oil impregnation stains are present in the samples, however, the devolatilization traces indicate gas formation. In some samples, partially degraded algae were observed. In the samples studied, fracturing is sporadic but oxidation is strong (Figure 6). The vitrinite reflectance of this formation ranges from 0.9 to 2.6 %. In addition, interpretation was not easy due to bitumen presence in many samples. The samples show higher type III organic matter content than type II organic matter.

Discussion

Vitrinite reflectance values in the Sabinas-Piedras Negras Basin suggest high gas formation and minimal oil formation. Each formation exhibits different thermal histories, thus, varied maturation evolution. The petrographic results indicate that the thermal events are linked to migration processes. Diverse migration pulses observed in the samples could be related to the thermal subsidence and the uplift in the region studied. This system could explain the different pyrobitumens and the variation of the geochemical parameters in the source rocks.

The oil migration could have occurred with a vertical component through the microfractures, and the gas migration through micropores. These phenomena seem to be dominant in the hydrocarbon mobilization in the samples analyzed because fracturing and microporosity are linked to the thermal history of the region - for example, the Olmos Formation presents a high evolution in its superficial levels.

By using the software Surfer, vitrinite reflectance distribution in the Sabinas-Piedras Negras Basin is represented in maps at different depths (Figure7). These maps show geographical variations: the vitrinite reflectance distribution changes direction with depth. Preliminary results suggest independent heat fluxes of the tectonic region.

Conclusion

The maturation in the source rocks observed through organic petrography in the Sabinas-Piedras Negras Basin shows rapid hydrocarbon formation and gas migration linked to the thermal history and burial of the basin. Hydrocarbon migration mainly occurs via fractures and pores.
In the samples studied (mostly, the La Casita Formation), the dominant organic matter is type III while type II is low. The hydrocarbons formed are essentially gas since the oil was transformed by secondary cracking. The La Casita Formation is the most important source rock in the Sabinas-Piedras Negras Basin due to its potential petroleum, its thickness, and its reservoir capacity. The petrological observations indicate that the La Casita Formation is a source and a hydrocarbon reservoir of other formation (may be La Gloria or Zuloaga Formations).

The other source rocks exhibit the same characteristics but they are thin. Moreover, fracturing is the most important factor, and it is probable that this phenomenon caused the loss of the hydrocarbons in the source rocks.

References


Figures

Figure 1. Location of the Sabinas-Piedras Negras Basin, Coahuila (NE Mexico).

Figure 2. Vitrinite (V) and inertinite (I) with exsudatinite (E) in the pores (Olmos Formation).

Figure 3. Eagle Ford Formation: disseminated organic matter and inertinite in the fractures.

Figure 4. La Peña Formation: fracture filled with disseminated organic matter and inertinite.

Figure 5. La Virgen Formation: disseminated organic matter and porous inertinite.

Figure 6. Oxidation and organic matter in the fractures (La Casita Formation).

Figure 7. Vitrinite reflectance distribution at 2200 m of the Sabinas-Piedras Negras Basin.
Figure 3. Eagle Ford Formation: disseminated organic matter and inertinite in the fractures.

Figure 4. La Pena Formation: fracture filled with disseminated organic matter and inertinite.