THE CONTRIBUTION OF THE SAN ANTONIO FORMATION FOR THE HYDROCARBON GENERATION IN THE EASTERN VENEZUELA BASIN

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ABSTRACT

Late Cretaceous "black shales" of the San Antonio Formation have been considered together with Querecual formation the most important source rock for the oils in the Eastern Venezuela Basin. In the type section (Querecual river), it is characterized by a sequence of shales, cherts and sandstones. This work present a detailed study of the San Antonio Formation in the type section which includes source rock quality (TOC, organic matter type and maturity), organic matter distribution (migration), paleoenvironment interpretations (biostratigraphy, elemental concentration and distribution) and characterization of radioactive geochemistry.
Keywords: shales, generation, migration, radioactivity, eastern basin, Venezuela

INTRODUCTION

The limestones, calcareous shales and cherts of the San Antonio Formation are considered a secondary source rock in Eastern Venezuela Basin. This formation has been studied in detail in its type section (Querecual River), including its quality as source rock, paleoenvironmental conditions of sedimentation, age, anoxic events, characterization of radioactive and geological and geochemical evidences of primary migration,. This work presents the integration of the studies carried out in the Universidad Central de Venezuela, between 1990 and 2008 of the San Antonio Formation in its type section, as a contribution of the detail study of Guayuta Group (López et al., 2006), making it one of the best studied stratigraphic section in Venezuela.

SAMPLES AND ANALYSIS

A total of 70 samples of limestones, calcareous shales, cherts and sandstones, were collected in the type section of the San Antonio Formation. The first group of fifteen samples (QASA) was used to determine the quality of the source rock (type of organic matter, TOC and maturity), and used also for paleoenvironmental interpretations and migration studies. The second group of fifty five samples (ARQKSA) was used for the age determination, paleobathymetry definition, and characterization of radioactive geochemistry.

RESULTS AND DISCUSSION

The mineral composition of limestones and calcareous shales is quartz, calcite, dolomite and pyrite. The sandstones have quartz, calcite, dolomite, pyrite and kaolinite. The TOC concentration for limestone and calcareous shales are between 1.7- 4.6 and present TOC between 2.7 and 7.3. The limestones and calcareous shales have low porosity (<1%) and permeability (<0.001 md). The TOC of sandstones varies from 0.3 to 2.2, porosities from 0.83 to 1.81% and permeability of 0.007 md. The results obtained by soluble organic matter (SOM) and SARA composition (average) in the QASA samples is presented in Table 1.

The limestones and calcareous shales are characterized by mixed organic matter (marine-terrestrial). The analysis of aromatic markers (phenanthrene, methylphenanthrenes, and methyldibenzothiophene) and pyrolysis Rock-Eval (Tmax > 470 °C) indicated a overmature source rock, whose potential for generation was high.

Table 1 Soluble organic matter (SOM, ppm). SARA composition (% w/w)

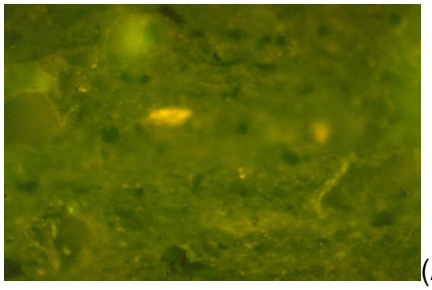
Concentration	Sandstone	Limestone Calcareous shales
SOM	293	660
Saturate hydrocarbons	44	52
Aromatic hydrocarbons	8	20
Resins	21	9
Asphaltenes	27	10

Concentrations of major elements St and $CaCO_3$ shows a decrease in the upper part of the section, and an increase of the SiO_2 concentration, associated to the decrease of the sulfate reducing conditions and the increment of clastic material. The Ni is present in low concentration in the upper part of the section (38-56 ppm) and it is not detected towards the top of the section (<20 ppm). These results and the values of V/Cr, V/Ni, V/V+Ni, Cu+Mo/Zn, Ni/Co and U/Th indicates that the O_2-H_2S limit is present in the sedimentary column, with increasing disoxic conditions towards the top of the section (Lugo, 2002).
The study of the concentration and distribution of major and trace elements allowed to identify mineral phases, the organic matter distribution, and to determine the association elemental with the organic matter or mineral phases present in the rock. The organic matter distribution, in this overmature rocks, and the abundance of fractures filled with organic matter without communication (Fig. 1), suggest a low bitumen expulsion efficiency due to organic matter distribution, mineralogical composition, porosity, permeability, texture and structure of the rock. However the n-alkanes distribution in a sequence of sandstones compared with the shale indicate the preferential migration of low molecular weight n-alkanes, compared with high molecular weight and isoprenoids phytane and pristine (Fig. 3).
The spatial distribution of major (C, O, Al, Si, P, S, K, Ca, Fe) and trace (V, Ni, Zn) elements was studied to determine the element associations with organic and inorganic phases using EPMA. These results show the association of Fe and S in pyrite replacement of fossil structures. The association of Zn and S shows the presence of sphalerite. These sulfides are present in low proportion and are related to low euxinic conditions. The mineral matrix shows the presence of calcite (association of C, O and Ca), quartz (Si, O) and kaolinite (Al, Si, O) in some zones the presence of K with Al, Si, and O suggests an illitization processes. Towards the bottom of the section C, O, Ca and Mg were observed in dolomite crystals, confirming the occurrence of a dolomitization process in this zone (Fig. 1). Only V and Ni are actually associated to organic matter.
Measurement of total natural radioactivity (total gamma rays) of the elements potassium, uranium and thorium showed low levels (< 120 cps) of radioactivity, as compared with Querecual Formation (770 – 1000 cps; Gómez, 2006; López et al., 2006).

CONCLUSIONS

The San Antonio Formation is considered as a secondary source rock for oils from the Eastern Venezuela Basin. Its organic matter is of mixed type (marine-terrestrial), deposited in an environment with an O_2-H_2S limit is present in the sediments column, with increasingly disóxic conditions towards the top of the section.

This formation has a high generation potential and presents an advanced maturity stage in the type section. However geological and geochemical evidences indicate a low level of generation of fractures and low communication of these fractures, suggesting low bitumen expulsion efficiency, with a preferential migration of light n-alkanes. Measurement of total natural radioactivity (total gamma rays) of the elements potassium, uranium and thorium showed lower levels of radioactivity than the Querecual Formation.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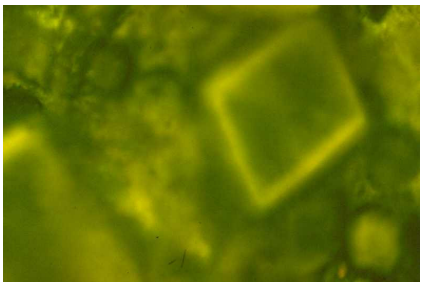
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Figure 1 Dispersed organic matter (A) and dolomite crystals (B). Scale: 50µ.

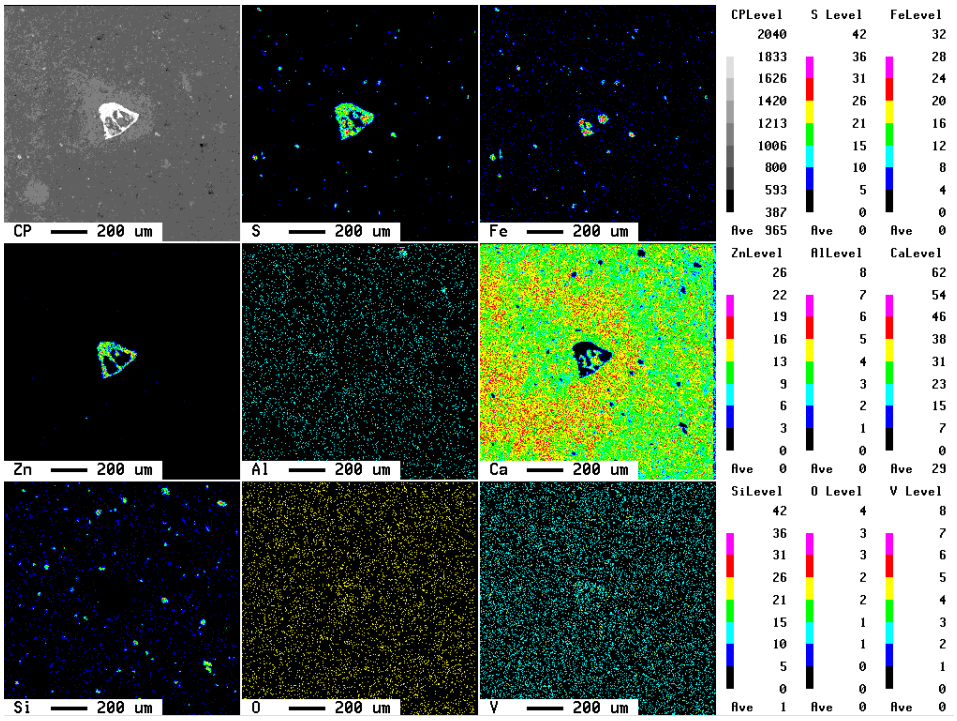

Figure 2 Compo image and map of elemental distribution.

ACKNOWLEDGMENT
This paper was supported by Projects CDCH UCV, Venezuela (PG-03-00-6518/2006) and TOTAL-LOCTI.

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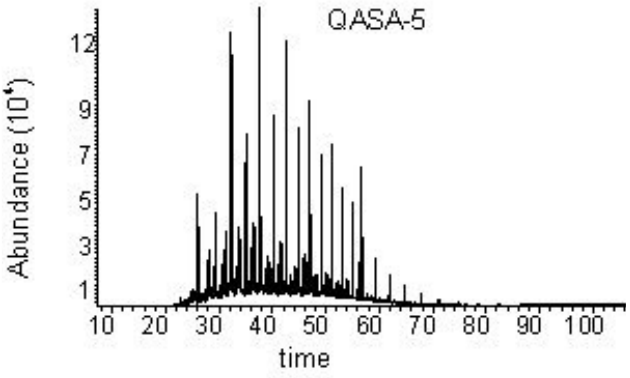
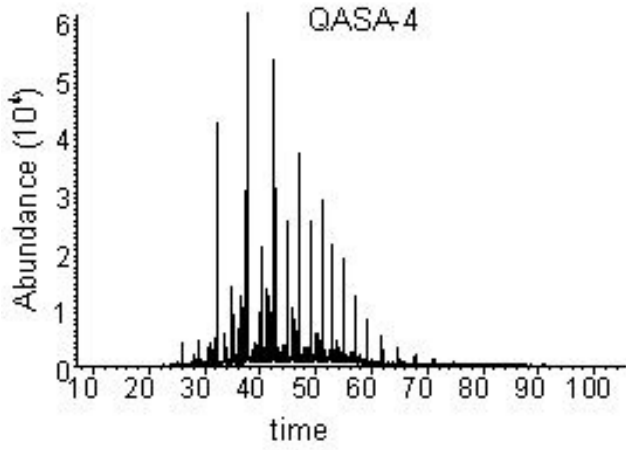
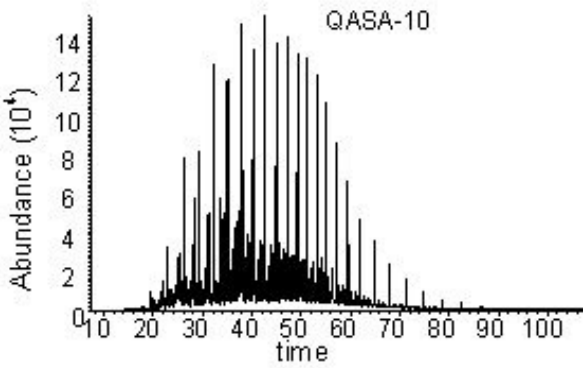
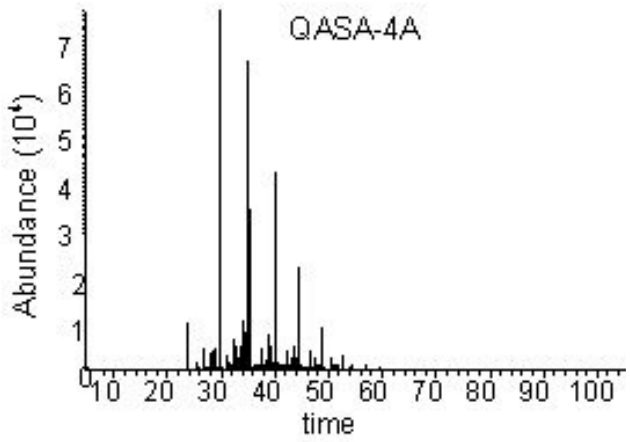






SHALE



SANDSTONE

Figure 3 Migration and expulsion evidences shale - sandstones.