Geochemical characterization and origin of Carabobo's area formation water, Orinoco Oil Belt, Venezuela

Moises Pirela[1], José Antonio García[2], José Rondón[1]

[1]Exploration and Reservoir Characterization Technical Management.

[2]Gas Technical Management

PDVSA Intevep Av. Santa Rosa, Los Teques, estado Miranda, Venezuela

E-mail: pirelamu@pdvsa.com**, Telephone: 58-2123308298, Fax:58-2123306742**

Congress Sub Theme: Energy and water resources

ABSTRACT

Orinoco Oil Belt (OOB) is regarded as the biggest accumulation of extra-heavy and heavy crude oil in the world. It located on the southern of Eastern Basin of Venezuela. 32 samples of formation water of different depth were extracted during the perforation of 11 stratigraphic wells, was determinated dissolved species concentration (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), alkalinity (HCO_3^- y CO_3^{2-}), pH, conductivity and temperature. The main objective of the present study was to characterize and to establish the origin of the formation water in the Carabobo's area through classical system (Stiff, Sulin y Piper). Piper's diagram allow to identify three types of formation water: Na-HCO_3, Ca-HCO_3 (C well) y Na-Cl-HCO_3 (D well). Stiff´s figures allow to identify that in the research area, exist predominance of formation water type Na-HCO_3 with meteoric origin in addition of determination a mixture zone at southwest of area. Finally, the application of standard systems it allowed the characterization and the birth determination of the formation water in the Carabobo's area from OOB.

INTRODUCTION

In the oil industry, the formation water requires a detailed geochemical and hydrologic characterization (Archer and Wall, 1994) since the establishment of type and origin of this bodies water allow it to deduce the vertical and horizontal proximity of a certain hydrocarbons reservoir, as well as providing esential parameters such as salinity to calculate the oil reserves (Archer and Wall, 1994; Fiorillo et al., 1983).

OOB is regarded as the biggest accumulation of extra-heavy and heavy crude oil in the world. It located on the southern of Eastern Basin of Venezuela, south of Guárico, Anzoátegui, Monagas and Delta Amacuro states, Orinoco river it represent southern bound. OOB covers an area of aprroximately 54,000 km^2, with 600 km from east to west and 70 km from north to south (Fiorillo et al., 1983).

OOB has been divided into four (4) operacional areas that from east to west which are called: Boyacá (formerly Machete), Junín (formerly Zuata), Ayacucho (formerly Hamaca) and Carabobo (formerly Cerro Negro) (Fig. 1).

In that sense, the main objective of the present study was to characterize and to establish the origin of the formation water in Carabobo's area through classical system (Stiff, Sulin and Piper) looking for its integration with the others fluids present in the reservoir.

METHODOLOGY

32 samples of formation water extracted of different depth were used for this study. These samples were extracted during drilling of 10 stratigraphic wells. The water samples were transferred from the collecting tool, avoiding any contamination with oil or drilling mud. Subsequently, the samples were stored in HDPE bottles with 120 mL capacity. Before to storage, HDPE bottles were treated with a little volume of HNO_3 (bidistilled) until to reach pH~2. This treatment avoid precipitation, co-precipitation and heavy metals adsorption on the walls of the container; finally bottles were washed with deionised water. Measurements of temperature, conductivity and pH were made in the field using a pH/Cond Thermo 4-star meter.

The water samples for the dissolved species (cation and anion) were prefiltered with 0.45 µm filters and acidified with HNO3 just for anion determination. Dissolved species determination were followed established procedure in ISO-11885 and ASTM D-4327 metodologic norm.

RESULTS AND DISCUSSION

The characterization of a particular body of water is based on the concentration of majority ionic species and the relation between them. To execute such a characterization, clasification and identification of type of water in the Carabobo´s area was prepared a Piper´s diagram (Fig. 2) that includes water formation samples at different depths, this enabled us to identify and to establish hidrogeochemical areas, depending on the concentration of the cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (HCO_3^-, CO_3^{2-}, Cl^- and SO_4^{2-}).

The analysis of Piper´s diagram allow to identify three types of formation water: Na-HCO_3 type corresponding to the majority samples, Ca-HCO_3 type (well C) and samples from well D corresponding to Na-Cl-HCO_3 type. Na-HCO_3 type represents kind of water that are mostly associated with hydrocarbons acumulations and acquire this feature, due to reduction of SO_4^{2-} to S^{2-}, in addition to having high concentration of total dissolved solid.

Several combinations of hydrogeochemical processes and water–rock interaction reactions have been proposed to explain the origin of this type of groundwaters as dissolution of $CaCO_3$ in the presence of biogenic CO_2, accompanied by Ca^{2+} for Na^+ ion exchange (Schofield and Jankowski, 2004). Herczeg et al. (1991) explain the presence of Na–HCO_3-rich groundwaters through three different reactions: the reaction of Na^+ with kaolinite to form Na-beidellite and H^+, the dissolution of $CaMg(CO_3)_2$ by H^+ which releases Ca^{2+}, Mg^{2+}, and HCO_3^-ions to solution, then the exchange of Ca^{2+} and Mg^{2+} for Na^+.

Another way to classify the water according to their source (connate or meteoric) is through Sulin´s relation which classifies a waterbody through its molar relation Na/Cl.

According to that relation, in Fig. 3 it can be seen that, with the exception of sample of well C, all samples show a molar relation Na/Cl>1 indicating meteoric origin. Additionally, this relation indicate taht most samples present excess of Na^+ (not compensated by Cl^-) indicate an additional source besides halite dissolution (Kharaka and Hanor, 2003). The Na^+ excess can be compared with HCO_3^- (Fig. 4), it show good correlation with line that possibly indicate excess of

Na^+ was generated by dissolution of sodium-rich mineral such as albite ($NaAlSi_3O_8$) (Cheng et al., 2006):

$$2NaAlSi_3O_{8\,(s)} + 2H_2CO_{3\,(ac)} + 4H_2O_{(l)} \longrightarrow 2Na^+_{(ac)} + 2HCO_3^-{}_{(ac)} + 4H_4SiO_{4(ac)} + Al_2Si_2O_5(OH)_{4(s)}$$

Those samples that deflect of this tendency indicate that another process must add Na^+.

On the other hand, Stiff's figures (Fig. 5 and Fig. 6) suggest an meteoric origin that match with show in Fig. 3 and further samples rise their meteoric character with depth. In some wells, as well C (shallower sample) and well D, Stiif´s figure show the existence of connate water although Na/Cl relation suggest a connate origin for well C sample and meteoric for well D samples. This fact indicate the presence of a mixture zone (Fig. 5) between connate water (Na-Cl) and meteoric water (Na-HCO_3) at southwest to study area or maybe indicate communication of sands in the reservoir. It recommended, to realize a study with chemical or natural tracers to determine the exactly spatial position of this mixture zone and choose between these possibilities.

CONCLUSION

The results generated in the various tests on samples of formation water for Carabobo´s area concludes that the research area there predominance water $NaHCO_3$ type proposing its genesis to a meteoric origin.

Shallower sample of Well C and samples of wellD suggest the presence of a mixture zone in the southwest area, including water NaCl type and water $NaHCO_3$ type.

As regards to origin, Stiff´s figures and Sulin´s relation show predominance of meteoric origin for mostly samples and rising this with increasing depth of sand that contains the aquifer.

Finally, the jointly application of standard system (Piper, Stiff and Sulin) allowed the characterization and possible birth determination for the formation water in Carabobo´s area from Orinoco Oil Belt.

REFERENCES

- Archer, J. and Wall, C. (1994) Petroleum Engineering: Principles and Practice. London.
- Cheng, J., McIntosh, J., Xie, X. and Jiao, J. (2006) Hydrochemistry of formation water with implications to diagenetic reactions in Sanzhao depression and Qijia-gulong depression of Songliao Basin, China. Journal of Geochemical Exploration; 88: 86-90.
- Fiorillo, G., Montiel, E., Iturralde, J., González, L., Funes, D., Boesi, T., Bass, I., Fanti, O. y Monsalve, O. (1983) Evaluación y Exploración de la Faja Petrolífera del Orinoco. [Informe Técnico 003104,83].v. 1-11.
- Herczeg, A.L., Torgensen, T., Chivas, A.R., Habermehl, M.A. (1991) Geochemistry of groundwaters from Great Artesian Basin, Australia. Journal of Hidrology. 126, 225-245.
- Kharaka, Y and Hanor, J. (2003) Deep fluids in the continents: I. Sedimentary basins. Treatise on Geochemistry 5, 147-158.

- Schofield, S y Jankowski, J. (2004) Hydrochemistry and isotopic composition of Na-HCO_3 rich groundwaters from the Ballimore region, central New South Wales, Australia. Chemical Geology; 211: 111-134.

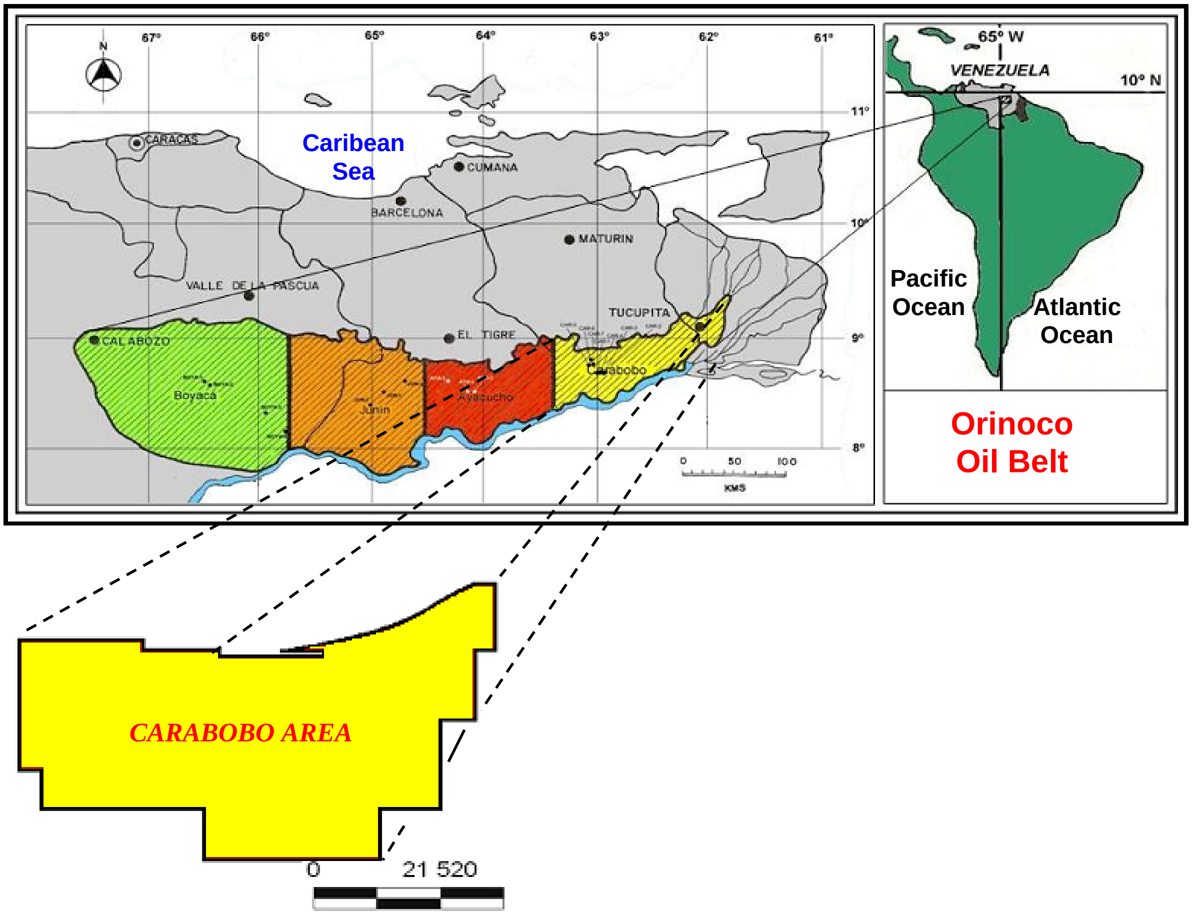

Fig. 1. Relative location of Carabobo area

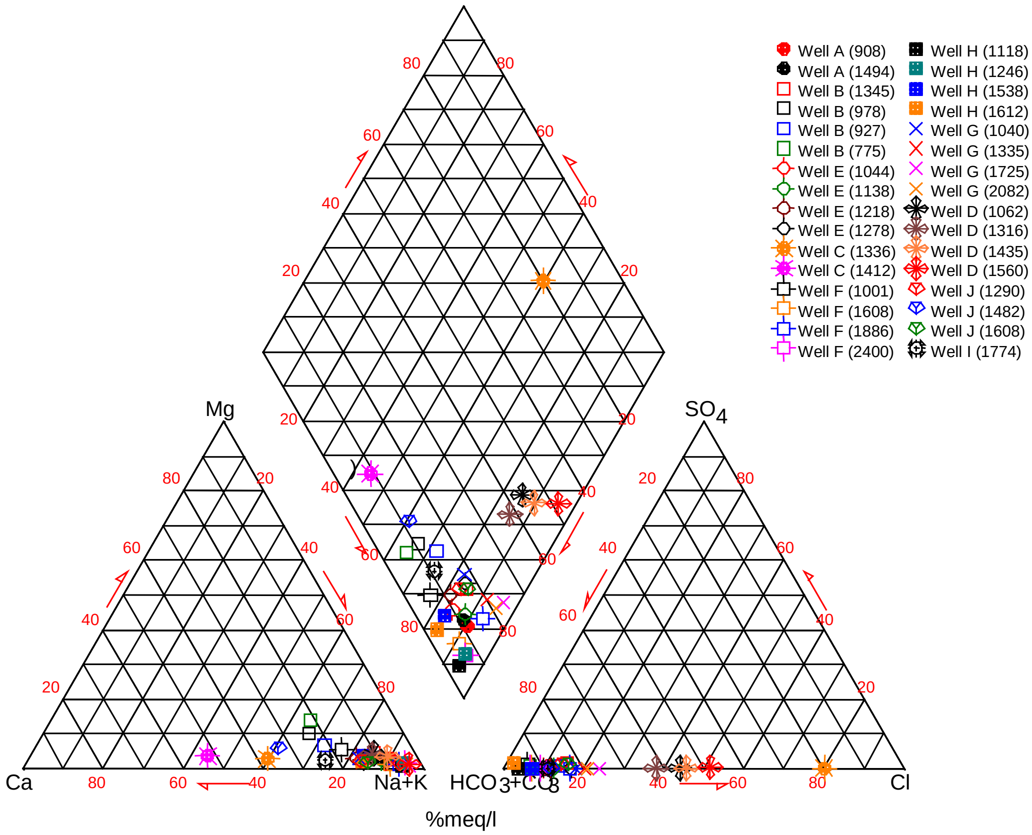

Fig. 2 Piper´s Diagram that show the type of water in Carabobo's area

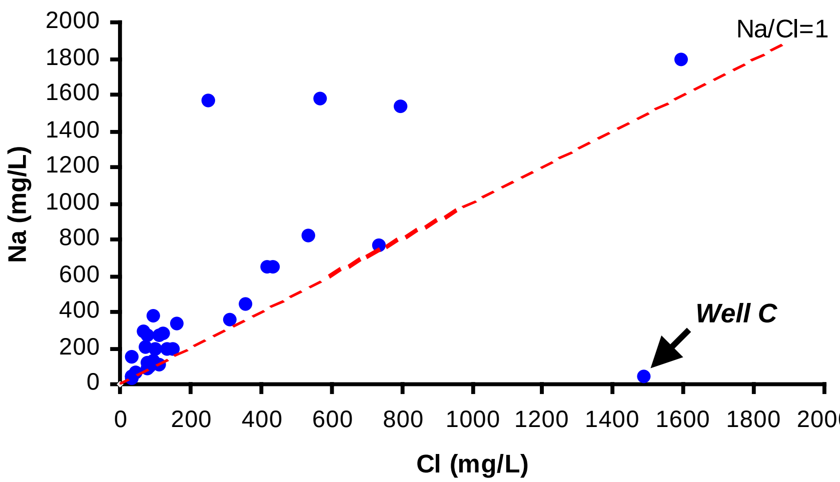

Fig. 3 Na/Cl relation of Carabobo's area formation water

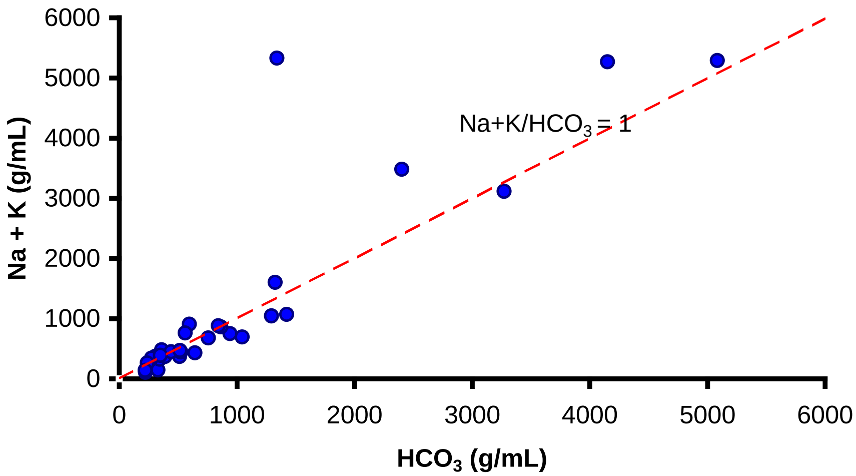

Fig. 4. Na+K/HCO_3 relation Carabobo's area formation water

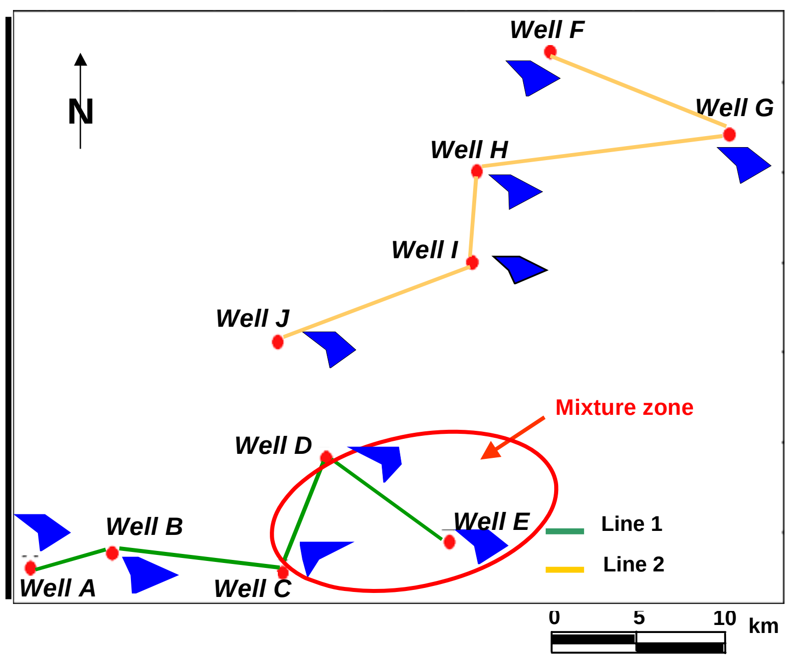

Fig. 5. Relative location of mixture zone (XY Plane)

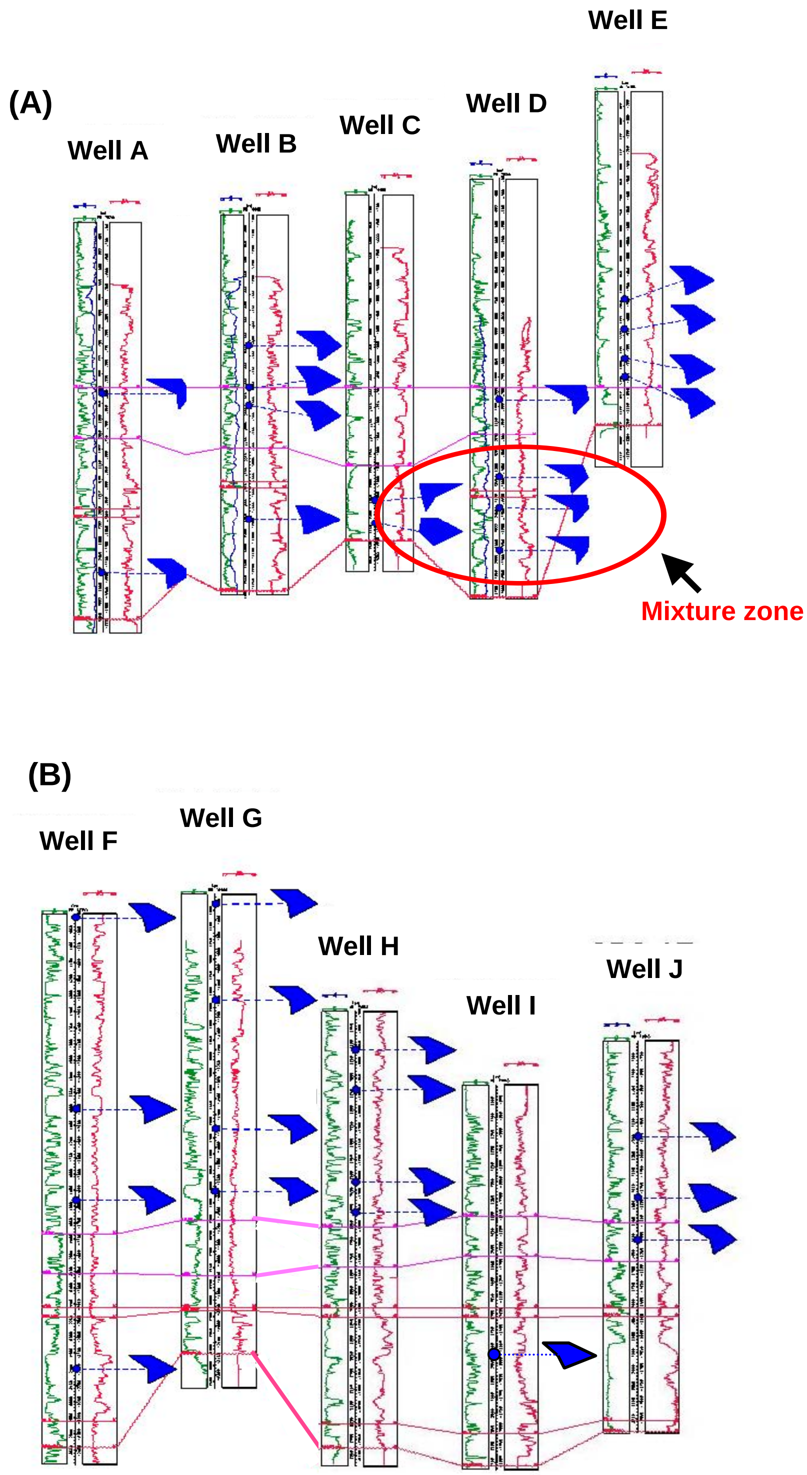

Fig. 6. Stiff's figures location in stratigraphic logs for Carabobo's area formation water (XZ plane) (A) Line 1; (B) Line 2