

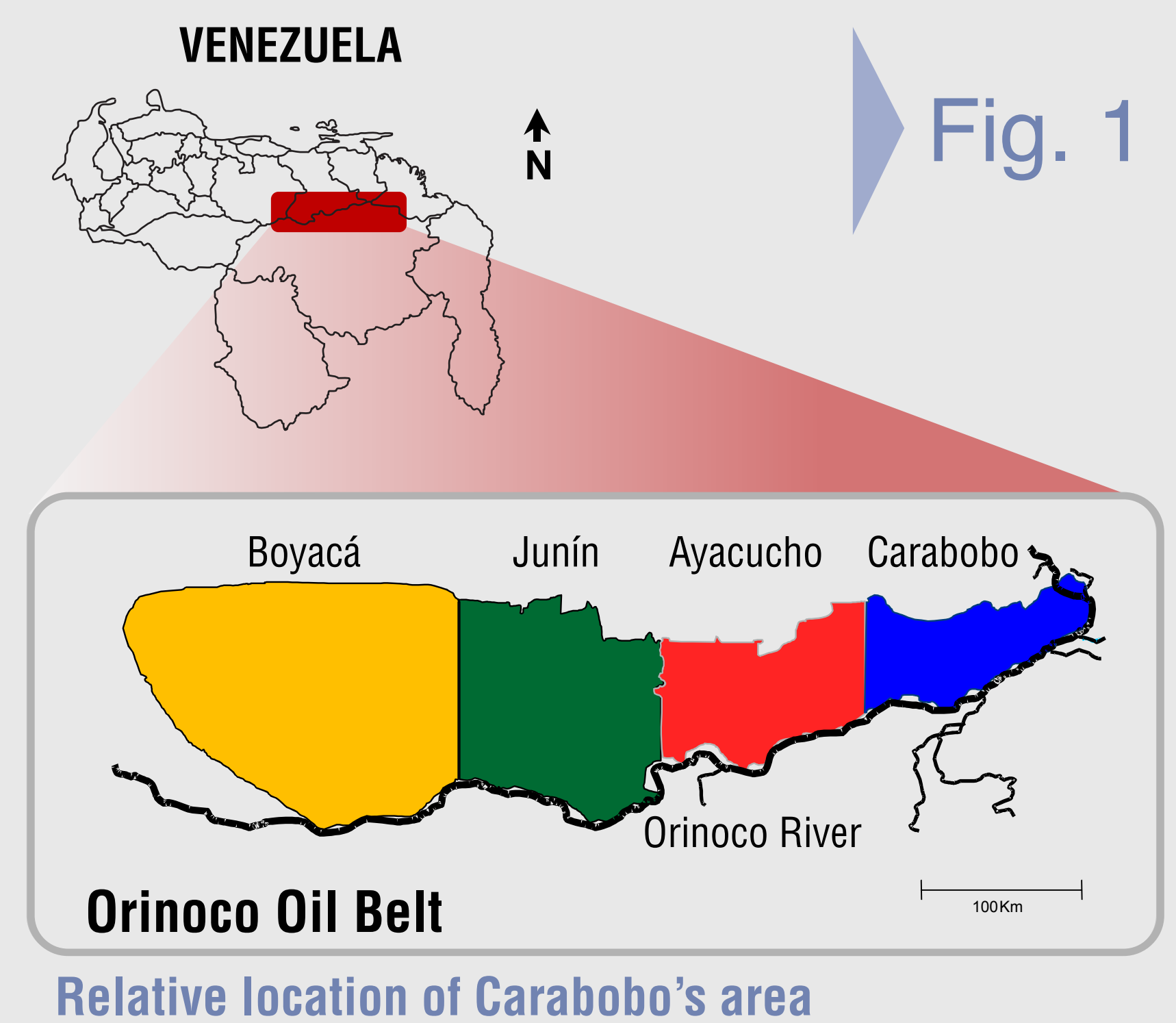
GEOCHEMICAL CHARACTERIZATION AND ORIGIN OF CARABOBO'S AREA FORMATION WATER, ORINOCO OIL BELT, VENEZUELA

INTRODUCTION

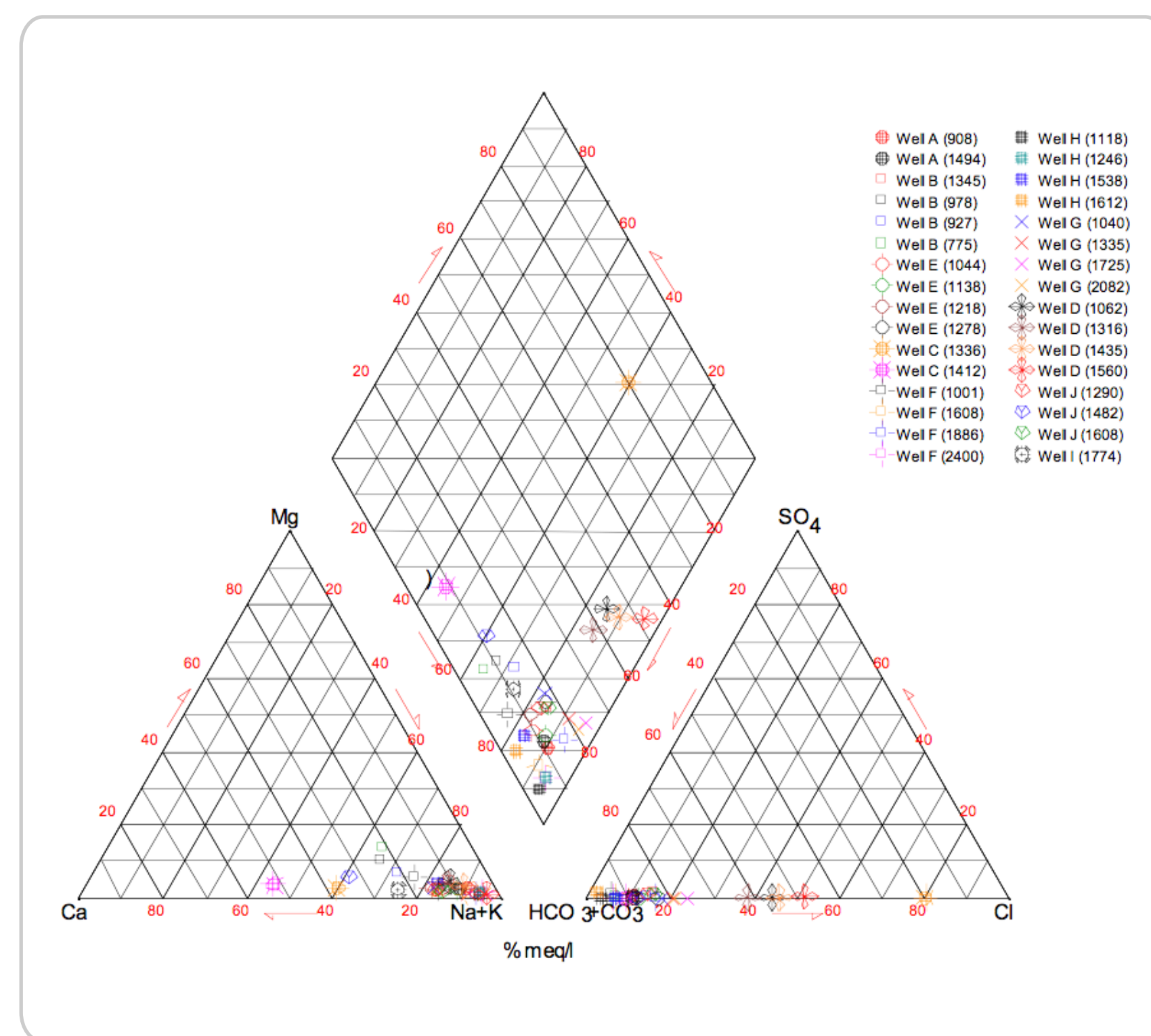
In the oil industry, the formation water requires a detailed geochemical and hydrologic characterization (Archer and Wall, 1994) since the establishment of type and origin of this bodies water allow it to deduce the vertical and horizontal proximity of a certain hydrocarbons reservoir, as well as providing essential parameters such as salinity to calculate the oil reserves (Archer and Wall, 1994; Fiorillo et al., 1983). 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, south of Guárico, Anzoátegui, Monagas and Delta Amacuro states, Orinoco river it represent southern bound. OOB covers an area of approximately 54,000 km², 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) operational 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).

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 HNO₃ (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



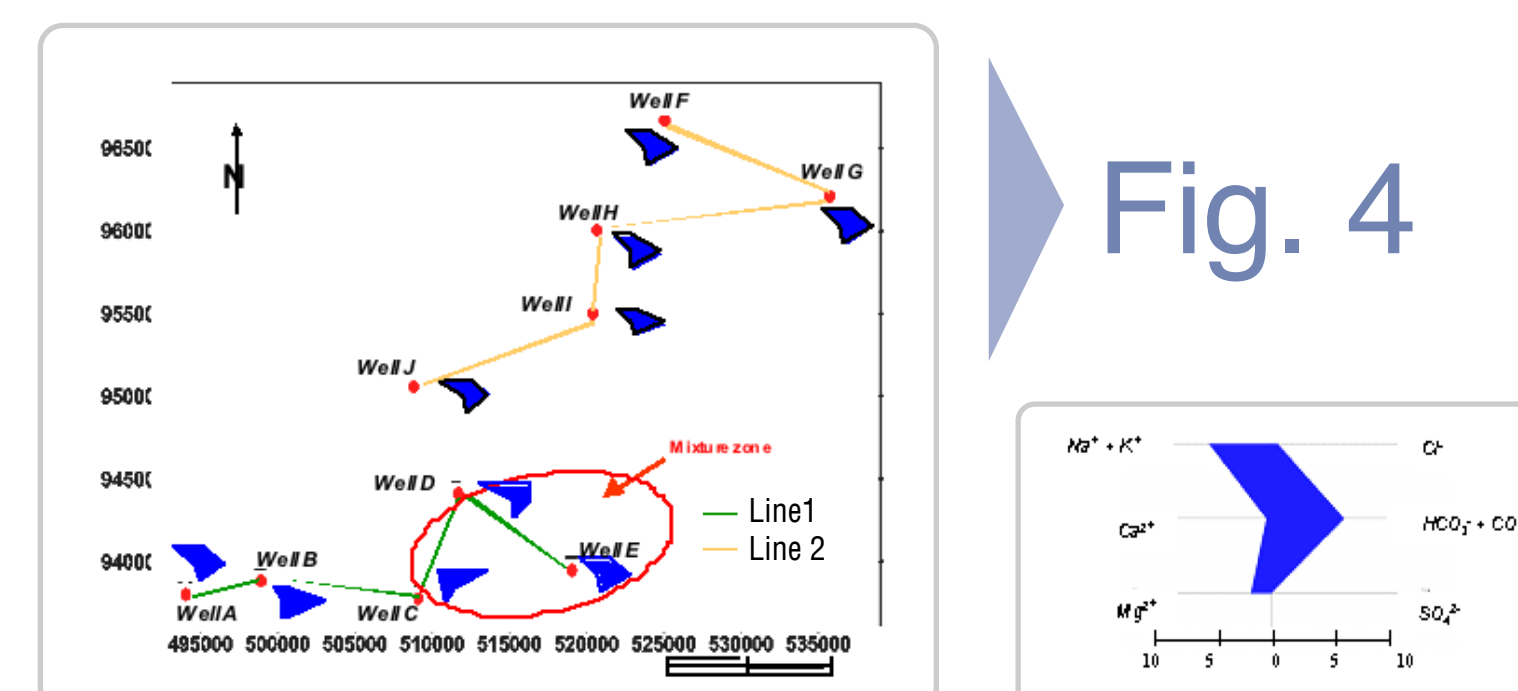
The characterization of a particular body of water is based on the concentration of majority ionic species and the relation between them. To execute such a characterization, clasification and identification of type of water in the Carabobo's area was prepared a Piper's diagram (Fig. 2) that includes 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⁺, Ca²⁺ and Mg²⁺) and anions (HCO₃⁻, CO₃²⁻, Cl⁻ and SO₄²⁻).

The analysis of Piper's diagram allow to identify three types of formation water: Na-HCO₃ type corresponding to the majority samples, Ca-HCO₃ type (well C) and samples from well D corresponding to Na-Cl-HCO₃ type. Na-HCO₃ type represents kind of water that are mostly associated with hydrocarbons acumulacions and acquire this feature, due to reduction of SO₄²⁻ to S²⁻, in addition to having high concentration of total dissolved solid.

Those samples that deflect of this tendency indicate that another process must add Na⁺. On the other hand, Stiff's figures (Fig. 4) 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, Stiff'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-HCO₃) 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.

Piper's Diagram that show the type of water in Carabobo's area

Fig. 2



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 CaCO₃ in the presence of biogenic CO₂, accompanied by Ca²⁺ for Na⁺ ion exchange (Schofield and Jankowski, 2004). Herczeg et al. (1991) explain the presence of Na-HCO₃-rich groundwaters through three different reactions: the reaction of Na⁺ with kaolinite to form Na-beidellite and H⁺, the dissolution of CaMg(CO₃)₂ by H⁺ which releases Ca²⁺, Mg²⁺, and HCO₃⁻ ions to solution, then the exchange of Ca²⁺ and Mg²⁺ 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 that 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 HCO₃⁻ (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 (NaAlSi₃O₈) (Cheng et al., 2006):

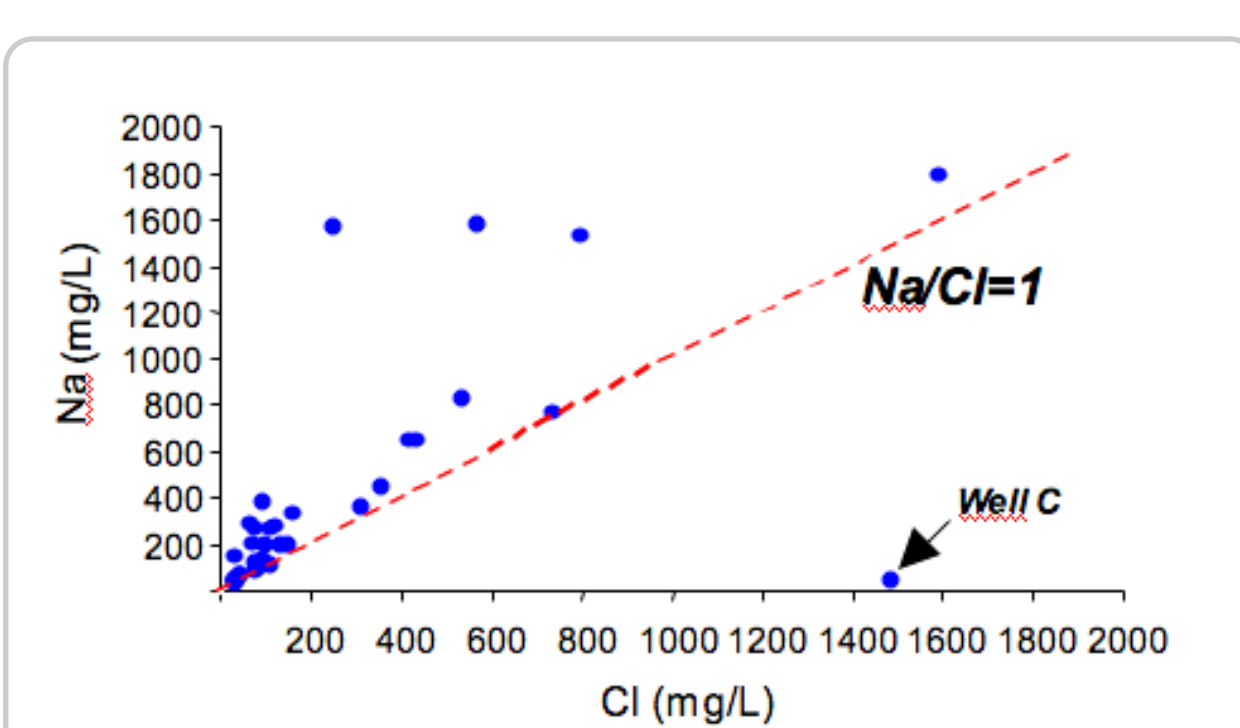
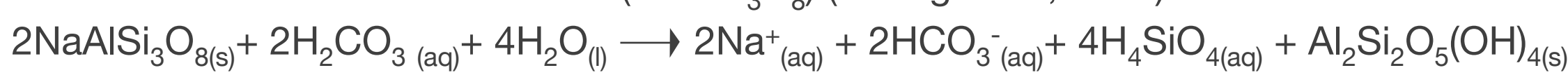
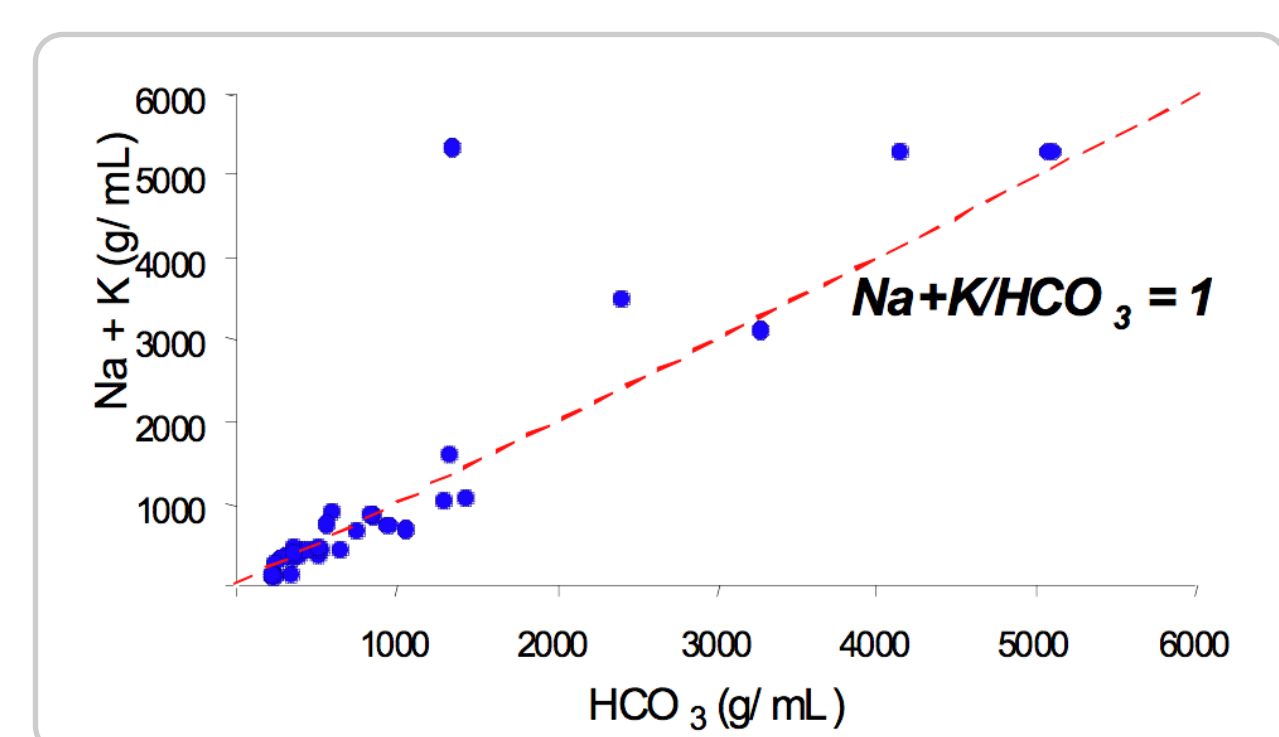


Fig. 3



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 NaHCO₃ type proposing its genesis to a meteoric origin. Shallower sample of Well C and samples of well D suggest the presence of a mixture zone in the southwest area, including water NaCl type and water NaHCO₃ 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.

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