[PS]Chemostratigraphy Across Devonian-Carboniferous Sedimentary Sequences at Roboré Sub-Basin, Southeastern Bolivia: Correlation and Tectonic Setting*

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Abstract

A chemostratigraphic analysis was performed on cutting samples from Devonian-Carboniferous intervals belonging to four wells located in the Roboré Sub-Basin, southeast Bolivia. From the multivariate statistical analysis (applying Factor Analysis-FA), it was possible to establish two main geochemical associations that control the chemistry of the analyzed samples: detrital (clay and heavy minerals) and redox-organic matter association. With the application of a hierarchical statistical analysis (constrained cluster analysis), the different geochemical zones (chemozones and sub-chemozones) were established, both for the detrital and redox-organic matter associations. A chemostratigraphic correlation scheme was made, achieving a total correspondence of the established chemozones. A better definition of the predefined stratigraphic contacts was obtained from the chemostratigraphic correlations. The general characteristics of the sources of sediment provenance along the sequences studied were evaluated, as well as the establishment of the tectonic setting. A passive margin tectonic setting is proposed for the arenaceous facies of the Tupambi Formation and active continental margin for the sediments of the Los Monos Formation.

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CHEMOSTRATIGRAPHY ACROSS DEVONIAN-CARBONIFEROUS SEDIMENTARY SEQUENCES AT ROBORÉ SUB-BASIN, SOUTHEASTERN BOLIVIA: CORRELATION AND TECTONIC SETTING

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ABSTRACT

A chemostratigraphic analysis was performed on cutting samples from Devonian-Carboniferous intervals belonging to four wells located in the Roboré Sub-Basin, Santa Cruz-Tarija Province, southeast Bolivia.

It was possible to establish two main geochemical associations that control the chemistry of the analyzed samples: detrital and redox association. With the application of a hierarchical statistical analysis, the different geochemical zones (chemozones and sub-chemozones) were established.

A chemostratigraphic correlation scheme was made, achieving a total correspondence of the established chemozones. A better definition of the predefined stratigraphic contacts was obtained from the chemostratigraphic correlations.

A passive margin tectonic setting is proposed for the sandy facies of the Tupambi Formation and active continental margin for the sediments of the Los Monos-Iquiri Formations.

Keyworks: Robore Sub-Basin; Chemostratigraphy; Tectonic Setting; Tupambi Formation; Los Monos-Iquiri Formations.

INTRODUCTION

Chemostratigraphy is a discipline that applies the study of variations in chemical attributes (inorganic and isotopic) for the characterization of stratified rock sequences. For more than 30 years, chemostratigraphy has been used as a fundamental tool in the correlation of hydrocarbon reservoirs (Craige, 2018). Although its use as a correlation tool has been the most widespread, recently the technique has increased its popularity in the resolution of other geological / geochemical problems.

The main objective of this work was to produce a chemostratigraphic correlation scheme for four wells that encompass a Devonian-Carboniferous sequence, located in the Roboré Sub-Basin, southeast Bolivia (figure 1). The analyzed interval included the potential hydrocarbon source rocks (Los Monos and Iquiri Fms) as well as the preferential reservoir (Tupambi Fm) of the proposed petroleum system for these basin. Additionally, it was sought to establish the tectonic setting of the main units.

STRATIGRAPHY OF ROBORE SUB-BASIN

The stratigraphic column of the Roboré Sub-Basin (figure 2) includes formations corresponding to the Proterozoic, Silurian, Devonian, Carboniferous and Jurassic-Cretaceous. The igneous-metamorphic basement presents a series of granites and gneisses of Proterozoic age. The Neoproterozoic comprises the Boqui, Tucavaca and Murciélago groups of the Ediacaran age. The Silurian is represented by the El Carmen Fm. The Devonian is preponderantly pelitic and is constituted by the Roboré Fm (Lower Devonian), synchronous with the Santa Rosa Fm and the Limón Fm (Middle Devonian) equivalent to Icla, Huamampampa and Los Monos-Iquiri Fms. (Upper Devonian). The Carboniferous is characterized by a sequence of conglomerates, sandstones, claystones and diamictites. The Jurassic-Cretaceous occurs sporadically with a sequence of sandstones and conglomerates of reddish colors corresponding to the El Portón Group, deposited in a fluvio-aeolian environment; discordantly, Tobité Fm (Upper Cretaceous) is deposited.

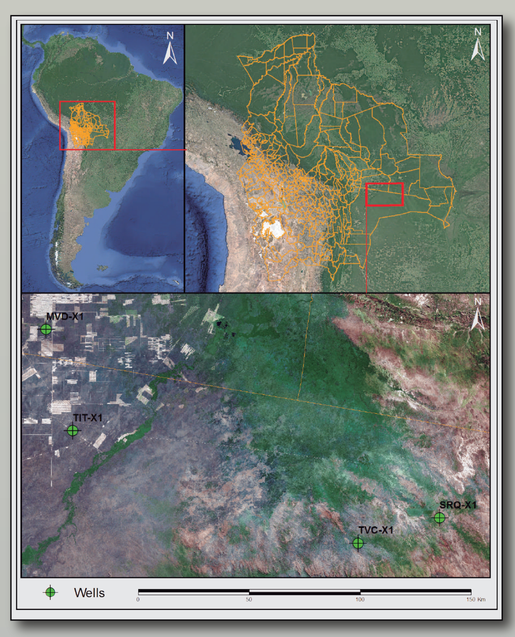


Figure 1. Wells location map.

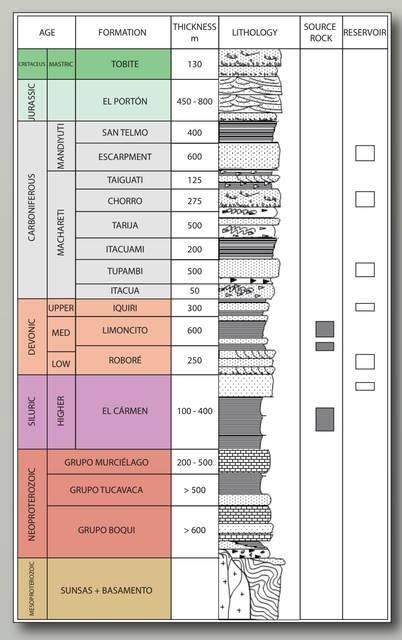


Figure 2.Stratigraphic column.

MATERIALS AND METHODS

A total of 280 samples of well cuttings were analyzed, from four wells (Tucavaca X1 (136 samples), Monteverde X1 (30 samples), Tita X1 (59 samples) and Sirimenquis X1 (55 samples)). Acquisition of data of chemical elements was carried out by the use of a Dispersive Energy X-Ray Fluorescence Spectrometer (EDXRF), Shimadzu, model EDX-720. From each run, the concentrations of 33 elements were acquired, including major (SiO_2, Al_2O_3, Fe_2O_3 (total), MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, S(total)), trace (Sc, V, Cr, Ni, Zn, Cu, Rb, Sr, Y, Zr, Mo, Cs, Ba, Pb, Th, U and As) and some rare earths elements-REE-(La, Ce, Eu and Gd).

RESULTS AND DISCUSSION

Geochemical association

Factor Analysis (FA) was the multivariate statistical technique used in the present study to identify important element associations, as elements occurring together in the same area of the F1:F2 binary diagrams (figure 3) are likely to have similar mineralogical affinities. The influences of quartz/clay/heavy minerals, redox-sensitive elements, drilling additives, carbonate and biogenic phosphate was recognize.

Figure 3. Binary diagrams (F1 vs F2) used to aid the establishment of geochemical associations.

Chemostratigraphic zonation

The establishment of the different chemozones (and sub-chemozones) was performed for each wells, using the different chemostratigraphic markers defined from the previously identified geochemical associations, specifically those that mark detrital associations (detrital chemozones). The "key" elements/ratios used was Si/Al; K/Al; (Ca+Na)/Al; Y/Sc, Rb/Sc; Y/Cr; Ti/Zr; ΣREE/Al; V/V+Ni; CIA ([Al/(Al+Na+Ca+K)]*100); and fragility index (Qz/(Qz+Crb+Cl)). Figure 4 show the chemostratigraphic profiles with their corresponding chemozones, defiened by hierarchical statistical analysis (cluster constrained; Montero-Serrano et al., 2010)

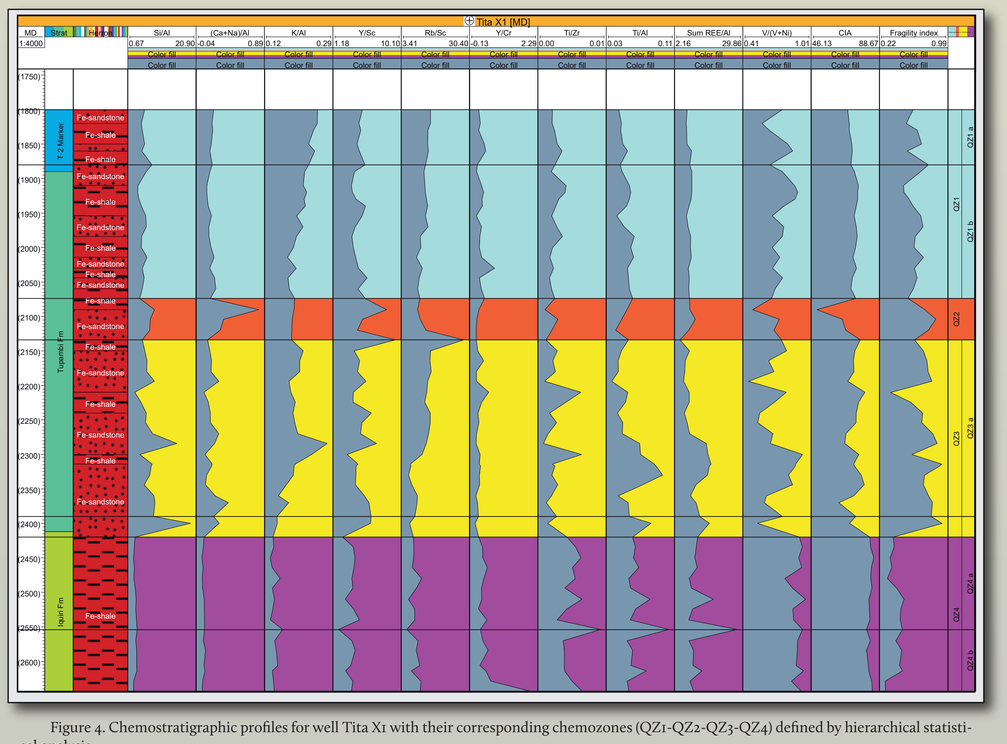
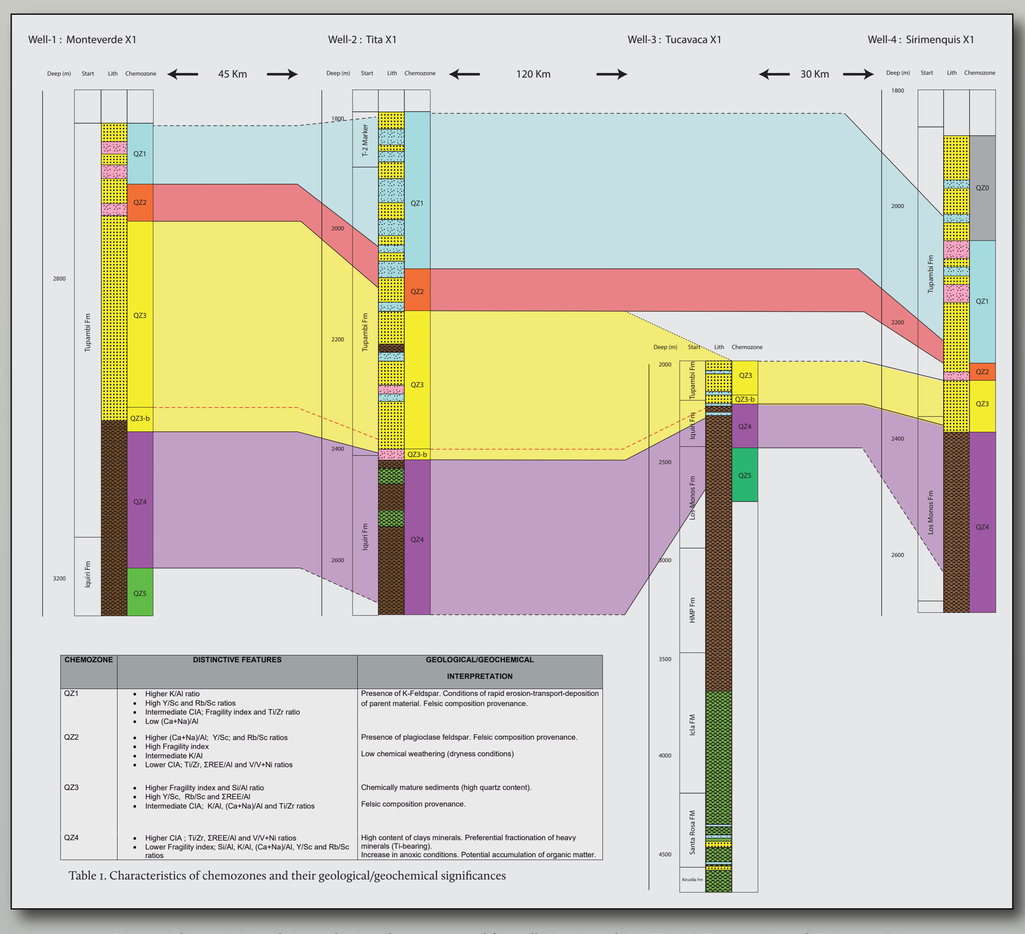


Figure 4. Chemostratigraphic profiles for well Tita X1 with their corresponding chemozones (QZ1-QZ2-QZ3-QZ4) defined by hierarchical statistical analysis.

Chemostratigraphic correlation

Figure 5 show a summary of chemostratigraphic correlation scheme between the study wells. The main characteristics of each chemozone and their geological/geochemical significance are summarize in table 1.



CHEMOZONE	DISTINCTIVE FEATURES	GEOLOGICAL/GEOCHEMICAL INTERPRETATION
QZ1	• Higher K/Al ratio • High Y/Sc and Rb/Sc ratios • Intermediate CIA; Fragility index and Ti/Zr ratio • Low (Ca+Na)/Al	Presence of K-Feldspar. Conditions of rapid erosion-transport-deposition of parent material. Felsic composition provenance.
QZ2	• Higher (Ca+Na)/Al; Y/Sc; and Rb/Sc ratios • High Fragility index • Intermediate K/Al • Lower CIA; Ti/Zr, ΣREE/Al and V/V+Ni ratios	Presence of plagioclase feldspar. Felsic composition provenance. Low chemical weathering (dryness conditions)
QZ3	• Higher Fragility index and Si/Al ratio • High Y/Sc, Rb/Sc and ΣREE/Al • Intermediate CIA; K/Al, (Ca+Na)/Al and Ti/Zr ratios	Chemically mature sediments (high quartz content). Felsic composition provenance.
QZ4	• Higher CIA ; Ti/Zr, ΣREE/Al and V/V+Ni ratios • Lower Fragility index; Si/Al, K/Al, (Ca+Na)/Al, Y/Sc and Rb/Sc ratios	High content of clays minerals. Preferential fractionation of heavy minerals (Ti-bearing). Increase in anoxic conditions. Potential accumulation of organic matter.

Table 1. Characteristics of chemozones and their geological/geochemical significances

Figure 5. Chemostratigraphic correlation scheme proposed for wells Monteverde X1, Tita X1, Tuvacava X1 and Sirimenquis X1.

Figure 6. La-Th- Sc and Th-Sc-Zr/10 plots for tectonic setting discrimination (after Bhatia and Crook, 1986). PM= Passive Margin; ACM= Active Continental Margin; CA= Continental Island Arc; OIA= Oceanic Island Arc

Approach to Tectonic Setting

Tectonic setting was establishment based on the interpretation provided by the distribution of trace elements in the samples analyzed. Following the triangular diagrams (figure 6) proposed by Bhatia and Crook (1986), it was possible to discriminate the general tectonic environment for the main formations present along on wells.

CONCLUSIONS

It was possible to establish two main geochemical associations that control the chemistry of the analyzed samples: detrital and redox.

A chemostratigraphic correlation scheme was made, achieving a total correspondence of the established chemozones. A better definition of the predefined stratigraphic contacts was obtained from the chemostratigraphic correlations.

A passive margin tectonic setting is proposed for the sandy facies of the Tupambi Formation and active continental margin for the sediments of the Los Monos-Iquiri Formations.

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