[PS]Applied Method to Evaluate the Petroleum System from a 2D Kinematic Model in the Sub-Andean Complex Zone and Thrust Belt*

Leodan Ramirez[1] and Dalma Veizaga[1]

Search and Discovery Article #42369 (2019)**
Posted April 22, 2019

*Adapted from poster presentation given at 2018 AAPG Latin America & Caribbean Region GTW, Optimizing Exploration and Development in Thrust Belts and Foreland Basins, Santa Cruz de la Sierra, Bolivia, June 6-8, 2018
 DOI:10.1306/42369Ramirez2019

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Abstract

The Tarija Basin is a large sedimentation domain extensively developed in Bolivia, where the petroleum systems corresponding to the oldest fields of the country are found, in which the geological processes that occurred after the deposition of the source rocks are abundant. It is the result of a complex evolution, in which it is not always possible to know exactly what happened over geological time.

Currently, exploration presents great challenges and must rely on different techniques and available new tools in order to make possible new discoveries while trying to reduce the inherent risk associated with any exploration process. With this in mind, nowadays there are several specialized software packages focused on specific technical areas that are of paramount importance in the definition of new prospects, such as PetroMod, which allows an analysis and visualization of petroleum system modeling using mathematical data algorithms that are incorporated to reconstruct the evolution of the sedimentary basin. The application of software with these benefits has direct implications in the evaluation of hydrocarbon potential when defining its prospectivity and analyzing the associated geological risks.

In this article, the main goal is to present the methodology that was applied to evaluate the petroleum system in a geologically complex zone - in this case in the Sub-Andean Thrust Belt in Bolivia - from a 2D Kinematic model for understanding hydrocarbon generation, migration and accumulation. Along a cross-section this model allows us to simulate the dynamic evolution of the sedimentary basin to determine if past conditions were suitable for hydrocarbons to migrate towards potential reservoir rocks and eventually get trapped and preserved. At the same time, the results provide a better understanding of the convergence of the necessary components and processes to generate and store hydrocarbons.

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Abstract

The main goal is to present the methodology that was applied to evaluate the petroleum system in a geologically complex zone -in this case in the Subandean thrust belt in Bolivia- from a 2D Kinematic model for understanding hydrocarbon generation, migration and accumulation. Along a cross-section this model allows us to simulate the dynamic evolution of the sedimentary basin to determine if past conditions were suitable for hydrocarbons to migrate towards potential reservoir rocks and eventually get trapped and preserved. At the same time, the results provide a better understanding of the convergence of the necessary components and processes to generate and store hydrocarbons.

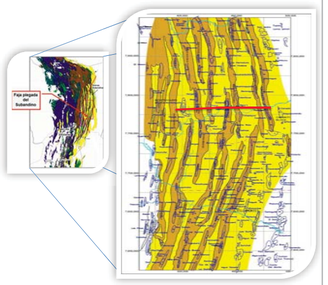
Objectives

- To present the methodology that was used for the elaboration of a 2D Kinematic Forward Modeling of the petroleum system in geologically Complex Zone and Thrust Belt.
- To check the performance of all the elements that make up the oil system through geological time, in particular, evaluate the synchronization of events, maturity of the generating rock, transformation rate and migration of hydrocarbons.

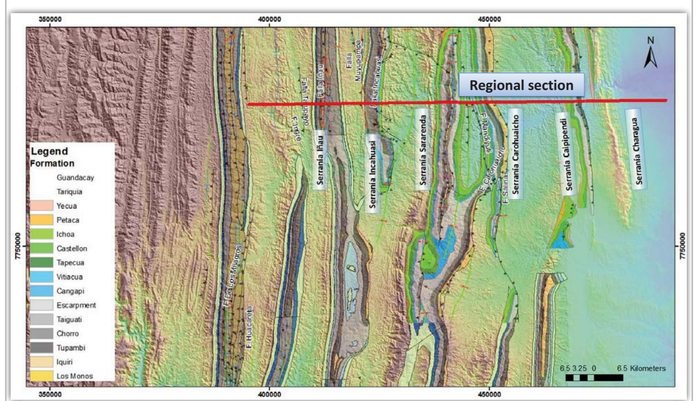
Background

LOCALIZATION OF THE STUDY

- The study area is located in the Tarija basin, it belongs to the group of sub-Andean basins that, during the Miocene, were formed as a single Amazon basin subjected to marine incursions. This sea stretched from northern Bolivia to Venezuela (Baby et al., 2005). The study area is a proven area of hydrocarbons potential due to the main oil fields of all South America is locating in this alignment.
- The total length of the transect is 70 km, it is the result of the union of 2 seismic lines, from east to west this crosses the Complex Thrust Belt, specifically through the Iñau plunge north, Incahuasi, Sararenda, Carohuaicho, Caipipendi and Charagua range; In this zones the main hydrocarbons are concentrated with a tested complex oil system.



Geological map and regional structural section.



Geological Framework

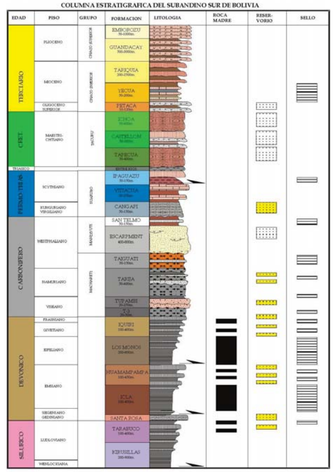
The Subandean Zone is a foreland fold and thrust belt the Eastern border of the Andes (Röder, 1988; Sheffels, 1990) and it is conformed by narrow anticlines of great continuity. According to Baby et. al. 1994, the structural style changes from one area to the rest, due mainly to the thickness and lithology variations of the rocks involved in the structural thrusting and detachment levels. The present study combines field work, subsurface data analysis, balanced cross-section, geochemistry data and thermochronological data.

SURFACE GEOLOGY

There are outcrops of the Tertiary system corresponding to the Petaca formation, also the Cretaceous-Jurasicc system corresponding to the Tacurú Group formations, as well as the Permo-Triassic system corresponding to the Cangapi formation. The formations that represent the Carboniferous System are the Escarpment formations belonging to the Mandiyuti Group and the Chorro / Tarija and Tupambi formations that belong to the Macharetí Group. From the Devonian System, the Iquiri formation partially appears in the Sararenda and Carohuaicho Range, to date no outcrops of the Los Monos formation have been recorded.

THERMOCRONOLOGY

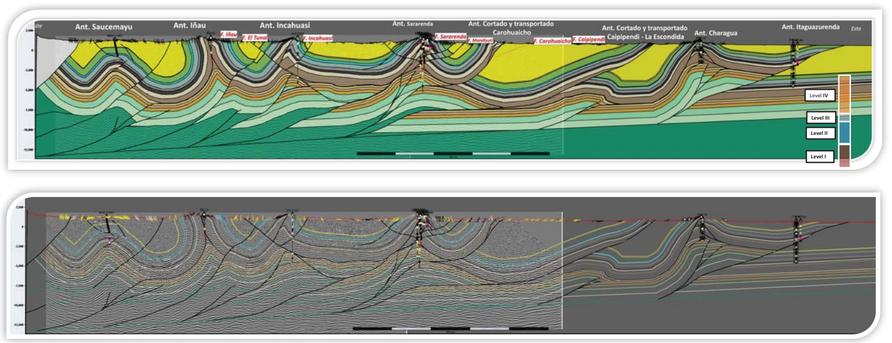
The Formation ages of each Range are not known exactly. For this study, the ages of evolution in the structure of the folded belt, were taken from dating in surrounding or neighboring mountains, these samples were dated in tuffs (U-Pb SHRIMP and LA-ICP-MS in zircons) for the Cenozoic and by geo-thermochronology (Apatite fission track) of units in the Carboniferous and Devonian to know variations in temperature in relation to the depth in a given time interval. Several of these data were acquired by XR Geomap for Petroandina SAM in the geological campaigns of 2011-2012, on the mountain ranges of Iñau, Incahuasi, Aguaragüe, San Alberto, Iñigüazu, Ingre and Yanguilo. These campaigns covered a large part of the Sub Andean Bolivian at South.



Generalized Stratigraphic Column of the South Subandean

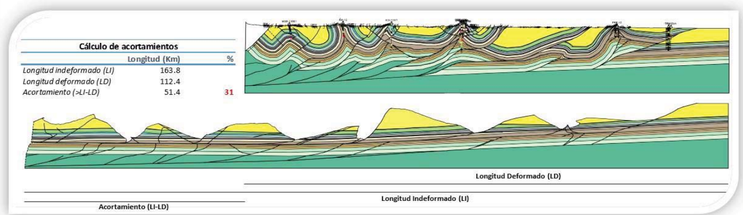
Structural Interpretation

Regional Structural Section using PSDM seismic



Stratigraphic Column

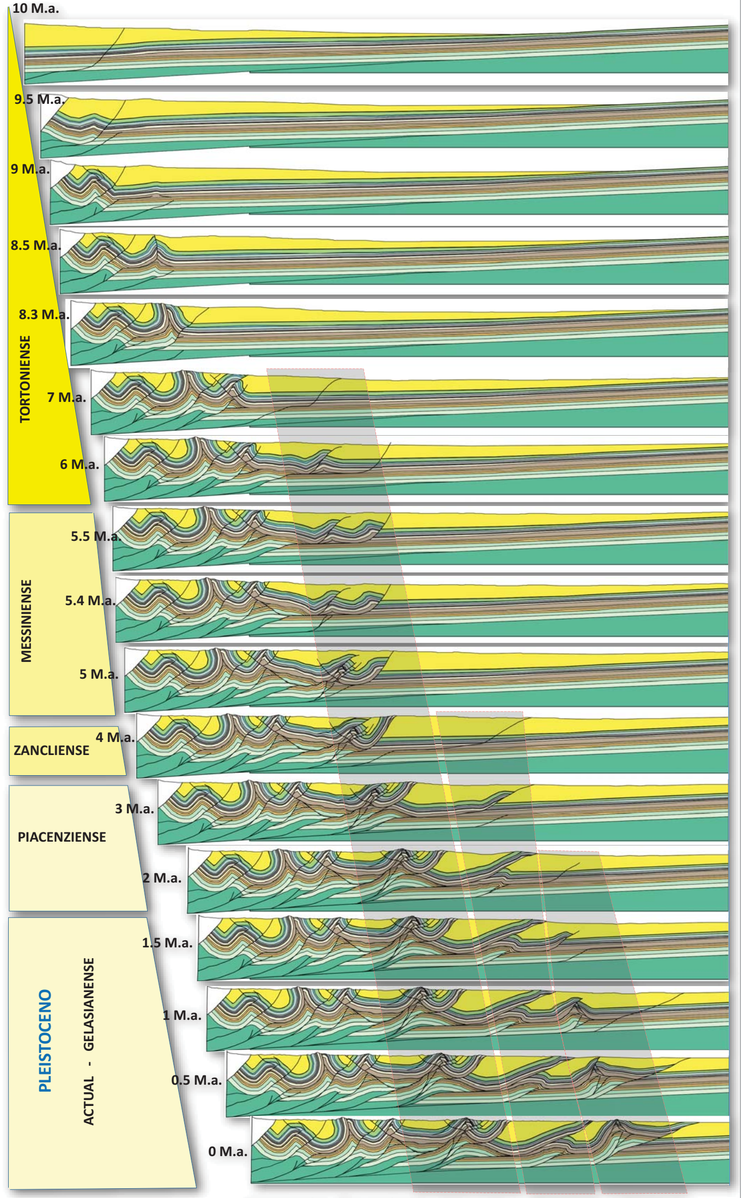
Structural model validation, balancing and regional restoration



The structural balancing was controlled using real thicknesses in each of the ranges, also, the deformed prism was interpreted taking into account lateral variation of thicknesses, which benefits greatly to reduce uncertainty about the true position of the structural highs of interest in the subsurface. The resulting shortening was 31%, for this zones from 30% to 40% shortening are considered feasible depending on the location.

2D Deformation Kinematic Model

The following figure shows the chronology in the deformation of the sedimentary prism involved, evolution and accommodation of the main faults that affect the indeformation system in the course of geological time



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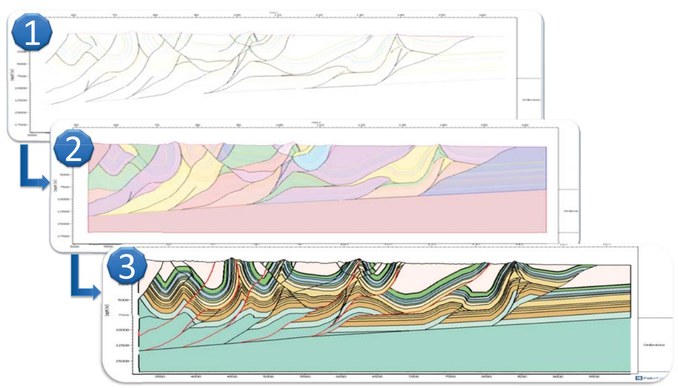
Model Building

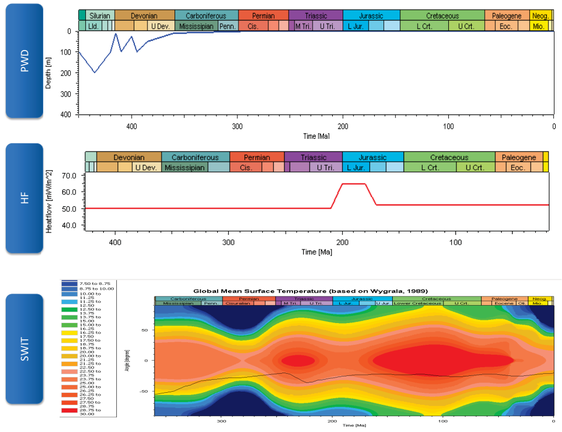


1. 17 palecoseccion were imported and the geological ages were assigned.
2. Creation, definition and assignment of 418 blocks and faults modeling.
3. Gridding, definition and lithological assignment.

Basin's Border Conditions

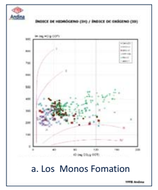
The basin´s border conditions were incorporated:

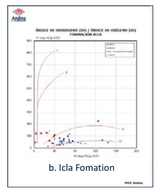
- **PALEO WATER DEPTH (PWD):** According to the sedimentary environments studied by several authors the paleoenvironments of the Siluric-Devonian cycle were defined; considering this information; a 200-meters depth in the Silurian and 100-meters in the Devonian was assigned for the deposits of pelitic marine platforms. For the remaining formations of the column a paleobathimetry of zero meters was assumed. This represents the marginal marine continental depositional environments that predominates in the stratigraphic column. (E. Rocha, 2013)
- **HEATFLOW (HF):** Currently in the Subandean, the amount of heat through the basin has been analyzed by several authors whom agree with the same hypothesis, that it is located within a range of values between 40 and 60 mW / m^2 (E. Rocha, 2013), it is assumed that the temperature during the "rifting" period between 200 and 220 Ma, would have increased reaching its maximum value of 65 mW / m2.
- **SEDIMENT-WATER INTERFACE TEMPERATURE (SWIT):** The surface temperatures were defined according to the global model of surface temperature proposed by Wigrala (1989). For this, the built-in module provided in PetroMod's was used.

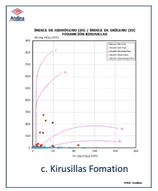


Geochemical Parameters

Name	Color	Lithology Value	TOC Mode	TOC Value [%]	TOC Map	Kinetics	HI Mode	HI Value [mgHC/gTOC]
Gr. Chaco_Facies_01		Gr. Chaco						
Petaca_Facies_01		Petaca						
Gr. Tacuru_Facies_01		Gr. Tacuru						
Gr. Cuevo_Facies_01		Gr. Cuevo						
Escarpment_Facies_01		Escarpment						
Charco-Carija_Facies_01		Charco-Carija						
Tupambi_Facies_01		Tupambi						
Iquiri_Facies_01		Iquiri						
Los Monos_Facies_01		Los Monos	Value	1.50		Pepper&Corvi(1995)	Value	200.00
Huamampampa_Facies_01		Huamampampa						
Icla_Facies_01		Icla	Value	1.14		Pepper&Corvi(1995)	Value	120.00
Santa Rosa_Facies_01		Santa Rosa						
Tarabuco_Facies_01		Tarabuco						
Kirusillas_Facies_01		Kirusillas	Value	1.41		Pepper&Corvi(1995)	Value	150.00
Ordovicico_Facies		Ordovicico						

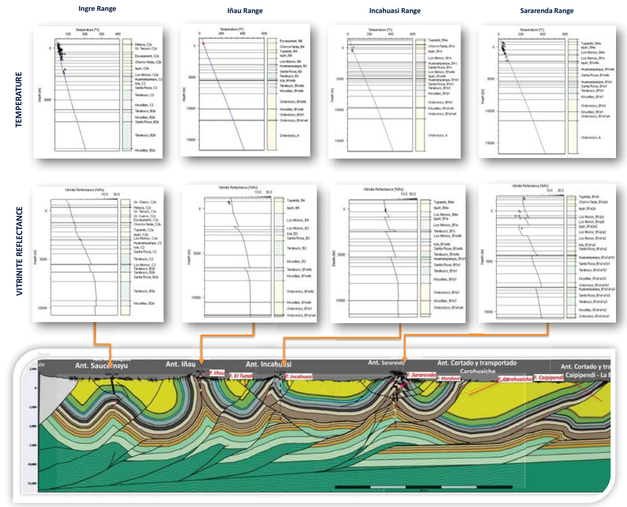






a. The Van Krevelen diagram is consistent with Type II and Type III kerogens, with mixed capacity for gas and oil generation.
b. The data of the samples are located very close to the horizontal axis, the IH close to zero and with a slight concentration in the fields of Type II and III and lower in the field of Type IV.
c. The predominant Type of kerogen is defined as Type III kerogen, with a tendency toward Type IV, reflecting conditions for gas generation. The tendency of some samples towards Type IV indicates a condition of marginal generator. Unfortunately, the information available is very limited.

Calibration



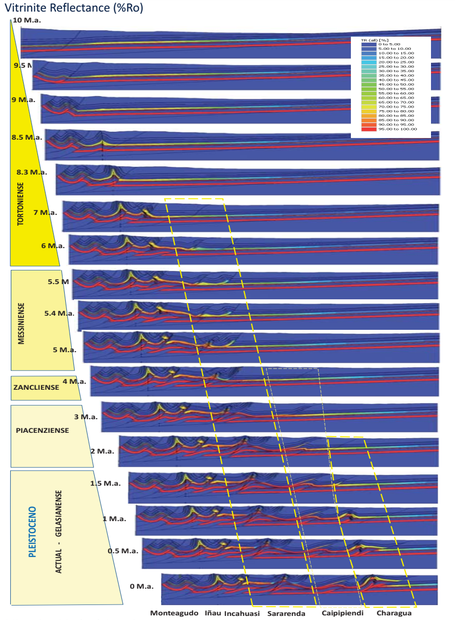
- To calibrate the temperature, the downhole temperature data was incorporated, as well as the reflectance of the vitrinite from the nearby wells. From the plotted data, the basin boundary conditions were modified; thus achieving the curve of temperature had a tendency according to the measured temperature, also the trend of the maturity curve is within the range of values of well data.

Conclusions

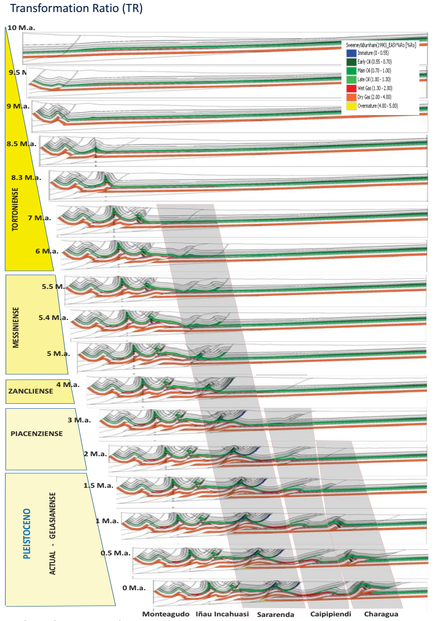
- Before the Andean deformation (10 MY) there was migration of fluids, after this event the migration is restricted to the configuration of the structures in the basin, using major faults and thrust as migration pathways.
- It is considered that the overburden during the Carboniferous was important to initiate the generation of hydrocarbons in the Kirusillas Formation.
- The first expulsion pulse from the source rocks it is related to the rift event in the Triasic-Jurasic age, and the second one is related to the Andean deformation.
- Despite of the results showing that the Kirusillas Formation would currently be found with values higher than 2.5% Ro classified as over matured rock, the contribution of hydrocarbons from it is not ruled out; because of previous studies which determined that the gases from the Devonian reservoirs show certain peculiarities in their distribution; in particular, the isotopic fraction of methane from Santa Rosa gas. This is attributed to a probable supply of dry gas from a very mature source rock presumably a Silurian or Devonian basal section. (Cruz et al., 2002).
- Los Monos Formation, due to the thicknesses of the tertiary deposits that are currently between 2,000 and 4,800 m, would be expelling mainly hydrocarbons in the late stage of oil generation close to an early stage of wet gas generation.
- The results obtained from the simulations carried out show hydrocarbon accumulations in the anticlines of known fields as Monteagudo, Incahuasi and Camiri.
- It's important to highlight that 2D modeling brings together diverse dynamic processes that allows us to study all the elements that integrate the petroleum system through the geological time.

Results

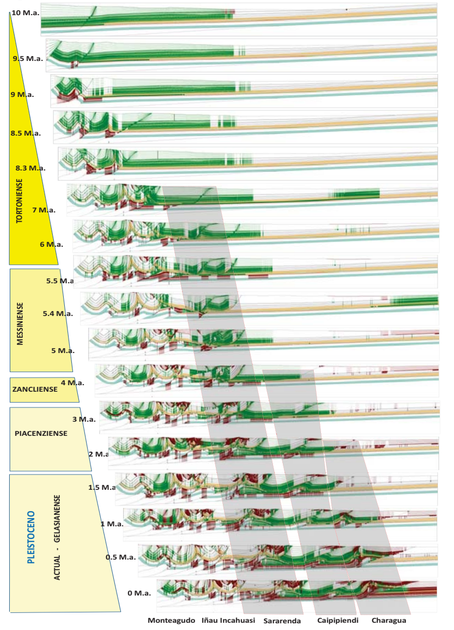
Vitrinite Reflectance (%Ro)



Transformation Ratio (TR)



Migration Method: Invasion Percolation



Hydrocarbon Accumulations