A New Approach for Production Forecasting in a Sub-Andean Overpressured Gas Reservoir Using Rate Transient Analysis: A Field Case Study*

Pedro Adrian[1], Ricardo M. Michel[1], and Franco F. Sivila[1]

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Abstract

The Bolivian Sub-Andean region is well known for exhibiting various complex fold-and-thrust belt structural reservoir systems. Because of such geological features, pressure and temperature settings are usually favorable for the occurrence of gas reservoirs, and even some of them exhibit overpressured reservoir conditions. Information provided by 2D and 3D seismic studies usually is limited and insufficient for a robust structural modeling which includes estimations of reservoir rock volume and Original Gas In-place (OGIP) with a high level of uncertainty. Thus, preparation of a production forecast at early stages of field development becomes a challenging task.

Additional conventional methods to determine the OGIP are material balance and numerical reservoir simulation. However, the volume of production and pressure history data required for application of any of them is considerable. Moreover, for the case of overpressured gas reservoirs where the depletion mechanism is affected by both water and rock compressibility effects, knowledge of the effective rock compressibility is essential if any reliable estimation of OGIP is desired. Nevertheless, if continuous reservoir monitoring is conducted, then it is possible to access valuable information that, if combined with Rate Transient Analysis (RTA) techniques, can overcome some of the aforementioned limitations and yield a useful estimation for the Original Gas In-place.

The use of Rate Transient Analysis (RTA) techniques has increased in the last decade, although its application to overpressured gas reservoirs has not been studied in depth. This work aims to perform a production forecast for an overpressured gas reservoir based on the analysis of daily production data by application of Rate Transient Analysis. The relation between pseudo-material balance time and the normalized pseudo-pressure drop presents a change in slope similar to the observed in conventional material balance plots. A case study for application of the proposed methodology is presented.

References Cited

Arif, R.H, A.R. Yusni, S.W. Panca, A.P. Eldias, A.A. Tri, E.P. Subihi, and S. Rahayu, 2015, Production Data Analysis: Estimating OGIP and Forecasting Gas Production Profile from Rough Data of Overpressured Gas Reservoir: SPE/IATM Asia Pacific Oil & Gas Conference, Nusa Dua, Bali, Indonesia, October 20-22, SPE-176209-MS.

Chilingar, G.V., V.A. Serebryakov, and J.O. Robertson, Jr., 2002, Origin and Prediction of Abnormal Formation Pressures: Elsevier Science, The Netherlands.

Fetl, W.H., and R.E. Chapman, 1994, Studies in abnormal pressures: Elsevier Science, The Netherlands.

Li, Y., B. Li, J. Zhang, J. Xia, Y. Jiao, H. Peng, X. Xiao, and H. Wang, 2016, A Systematic Dynamic Characterization Method for Abnormally High-Pressured Gas Reservoirs: Offshore Technology Conference Asia, Kuala Lumpur, Malaysia, March 22-25, OTC-26738-MS.

Tiab, D., A. Igbokoyi, and D. Restrepo, 2007, Fracture porosity from pressure transient data: International Petroleum Technology Conference, Dubai, UAE, December 4-6, IPTC 11164.

Van Golf-Ratch, 1982, Fundamentals of fractured reservoir engineering: Elsevier Science, The Netherlands.

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- Introduction
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- Methodology
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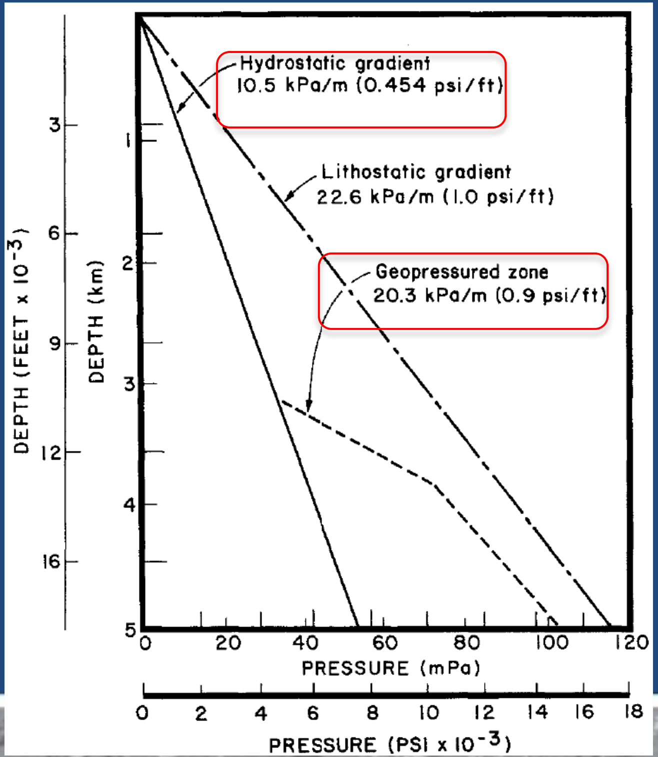
- Conclusions

Introduction

Abnormal pressures

Chilingar et al. (2002)

- Types:
  - Subpressures or Low formation pressures (ALFPs) (USA, Canada, Russia and Middle East)
  - Surpressures or High formation pressures (AHFPs) (Bulo Bulo, Caigua, Caranda, Tacobo, Los Monos fields)



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Abnormal pressures

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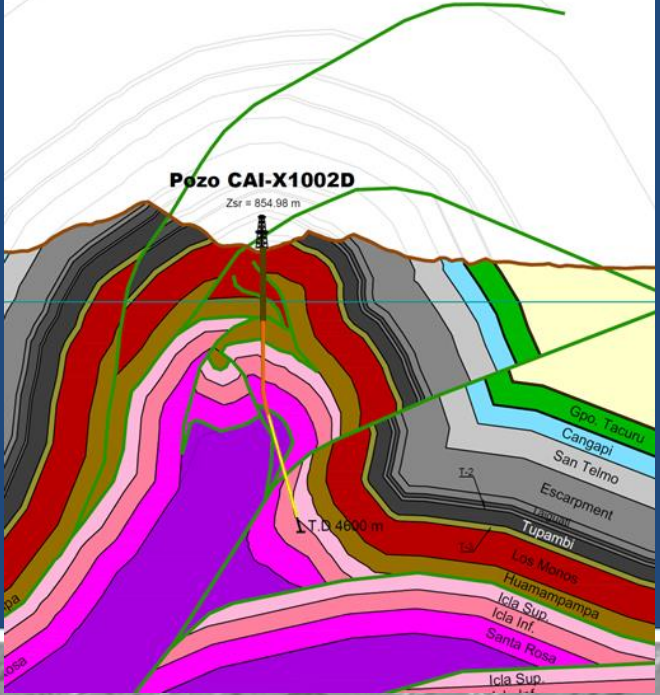
- Origins of AHFPs
  - Compaction, **tectonic compression, faulting**, diapirism, high geothermal gradientes, etc.

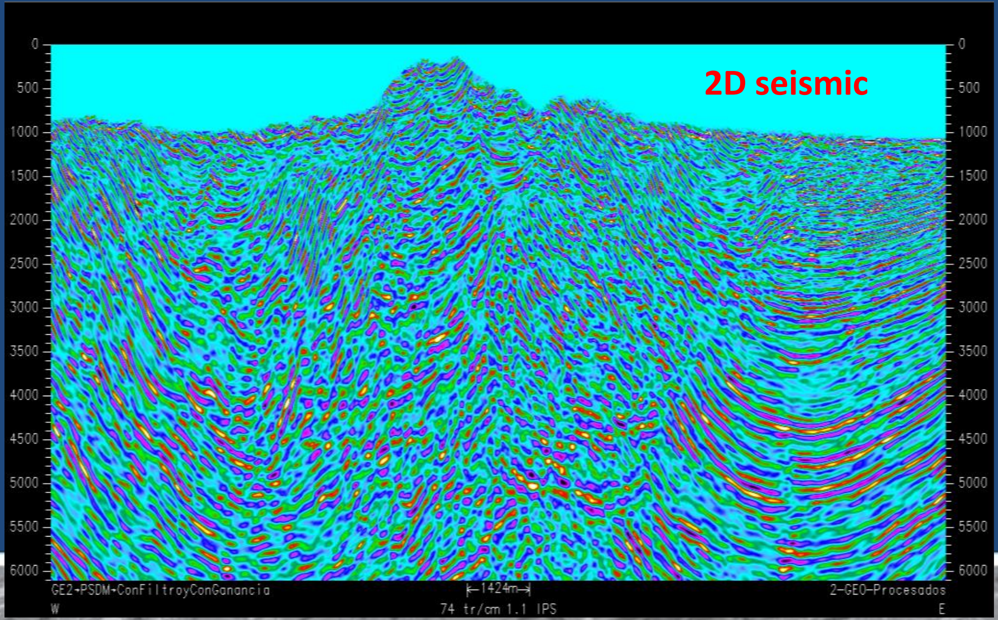
Sub-Andean fold and thrust belt

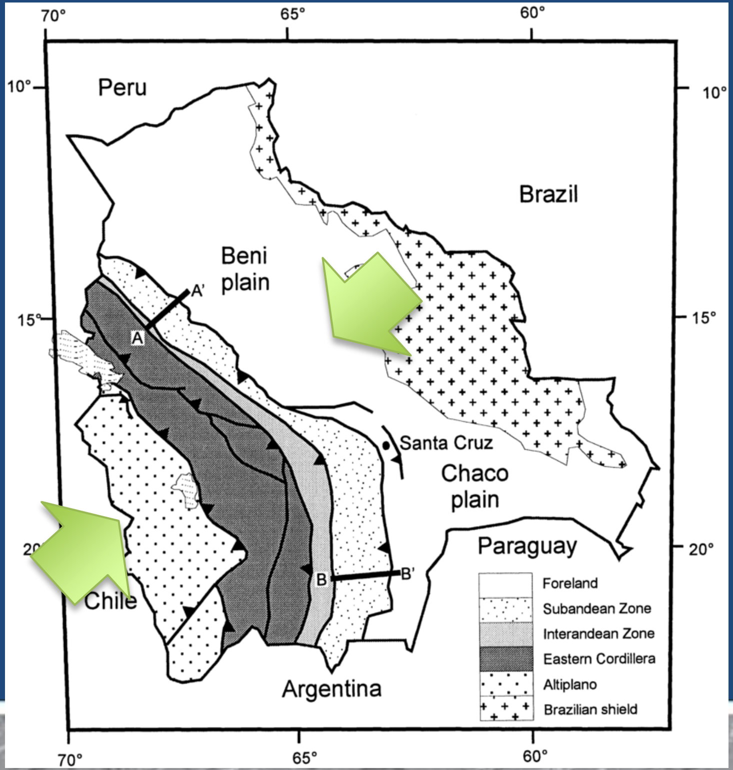


Introduction

Sub-Andean fold and thrust belt:

- Complex structural interpretations

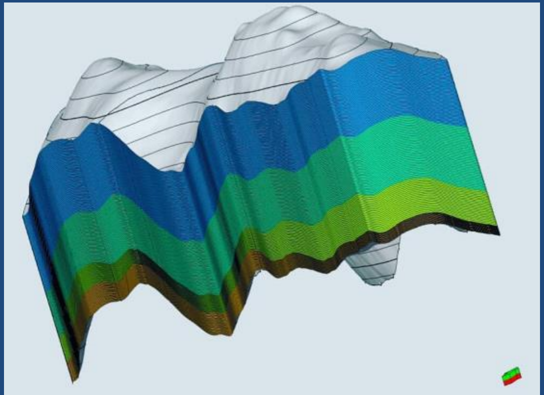


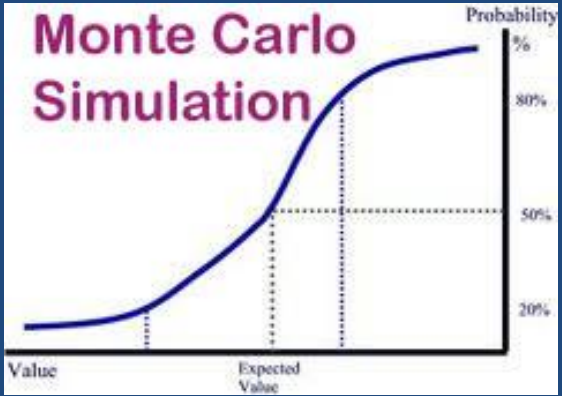


Introduction

Production Forecast:

- Early Stage: Volumetric Method
  - Monte Carlo
- Late Stage:
  - Material Balance
  - Numerical Simulation





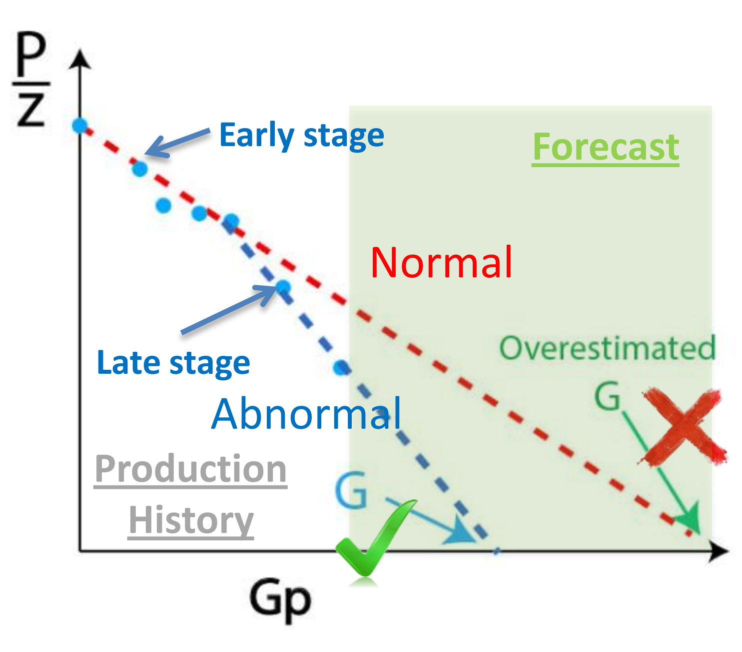
Introduction

Production Forecast:

- Early Stage: Volumetric Method
  - Monte Carlo
- Late Stage:
  - Material Balance
  - Numerical Simulation

} Dynamic Information

Rock compressibility (cf)
- Lab
- Correlation
- Production history

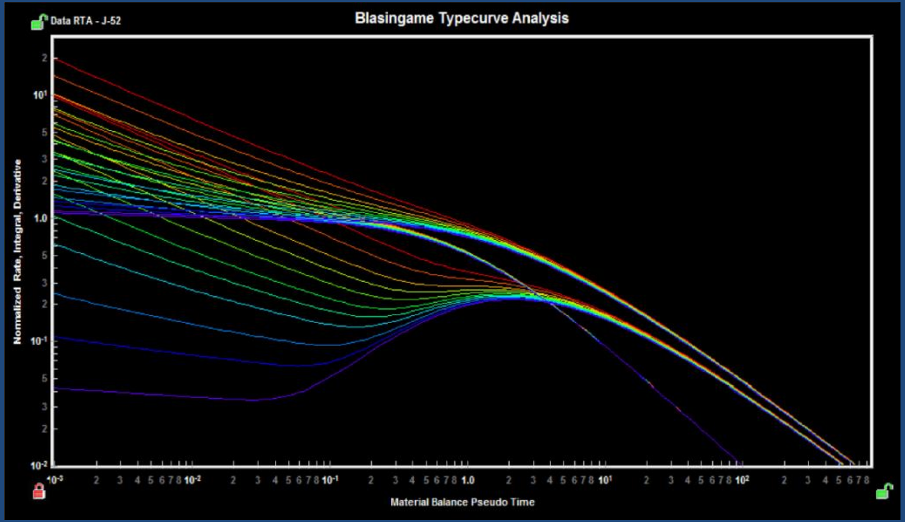


Introduction

Production Forecast:

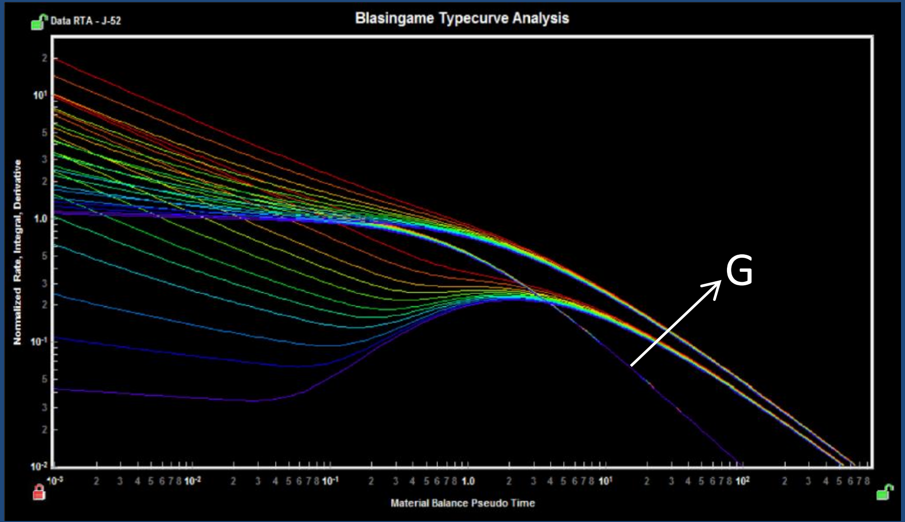
- Early Stage: Volumetric Method
  - Monte Carlo
- Late Stage:
  - Material Balance
  - Numerical Simulation
  - Rate transient analysis

Is it possible to apply?

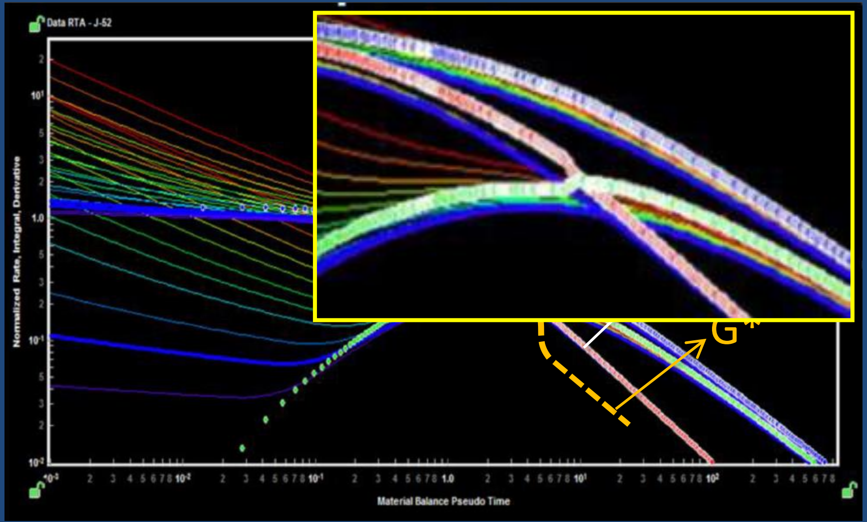


Literature Review

Arif et. al. (2015): OGIP and Forecasting Over-Pressured Gas Reservoir



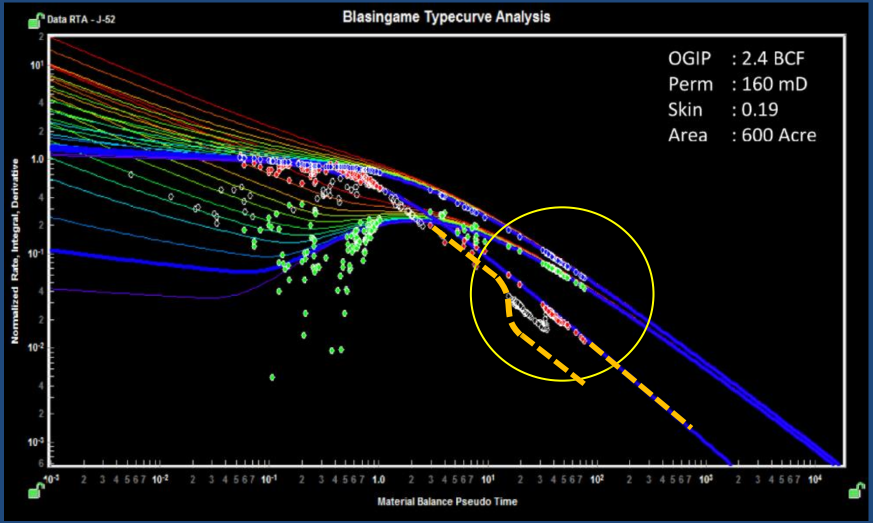
Synthetic data set from **normal pressured** reservoir



Synthetic data set from **over-pressured** reservoir

Literature Review

Arif et. al. (2015): OGIP and Forecasting Over-Pressured Gas Reservoir



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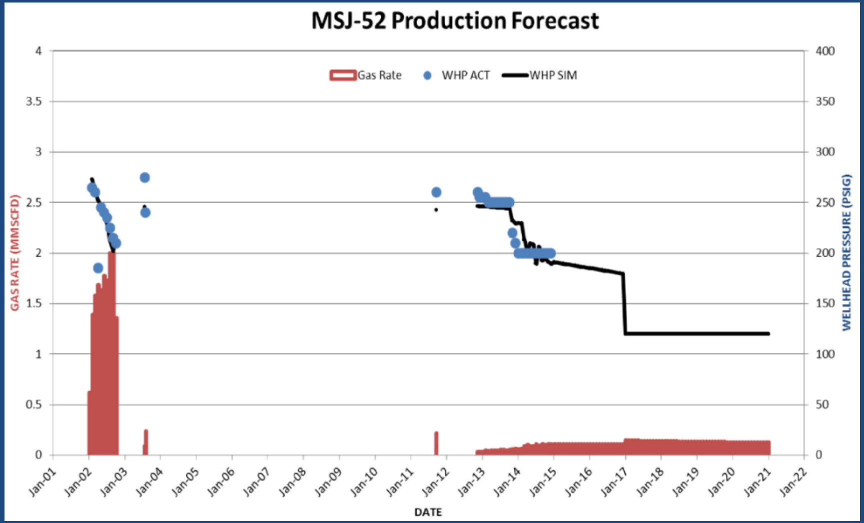


MSJ-52 History Match match

Literature Review

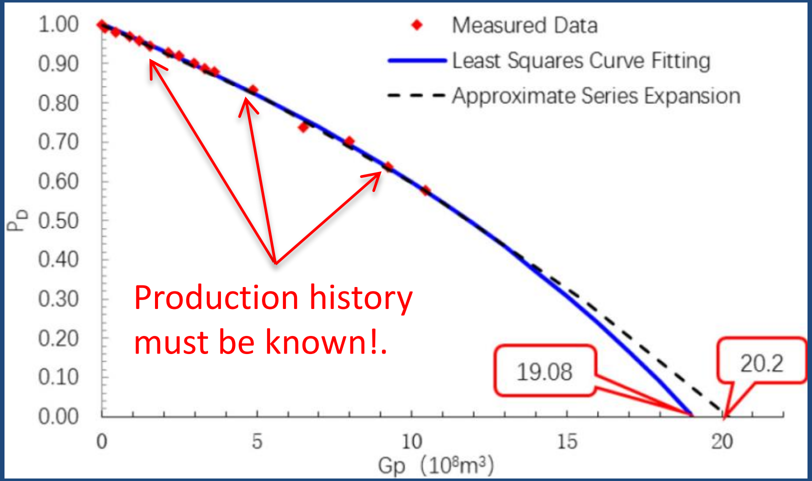
Li et. al. (2016): Abnormally High-Pressured Gas reservoir with aquifer support

$$\frac{P}{z}\left[1-\frac{c_w S_w + c_r}{(1-S_{wi})}\Delta P - \frac{W_e - W_p B_w}{G B_{gi}}\right] = \frac{P_i}{z_i}\left(1-\frac{G_p}{G}\right)$$

$$\frac{P}{z}\left[1-\omega G_p - \delta G_p\right] = \frac{P_i}{z_i}\left(1-\frac{G_p}{G}\right)$$

$$P_D\left[1-\lambda G_p\right] = \left(1-\frac{G_p}{G}\right)$$

Material Balance



Literature Review

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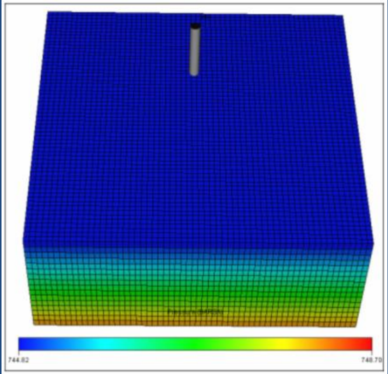
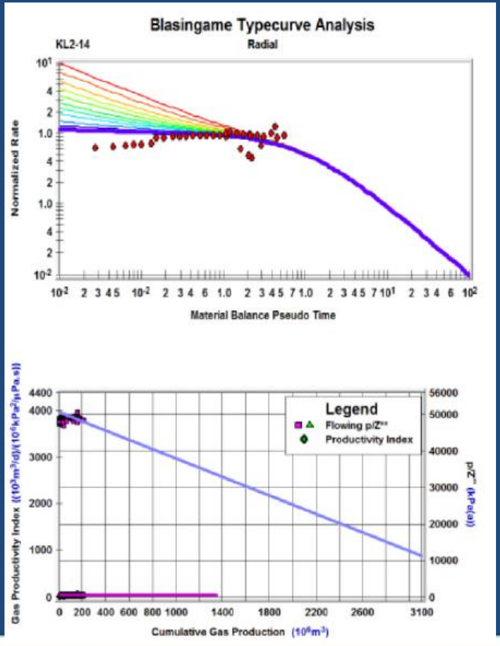
- No Aquifer + No Stress sensitive
- No Aquifer + Stress sensitive
- Aquifer + No Stress sensitive
- Aquifer + Stress sensitive





Systematic method: **MB, RTA, PTA.**

↳ Low in accuracy

Objective:

- Improve reliability of production forecast in Over-pressured gas reservoirs through the application of RTA method

Methodology

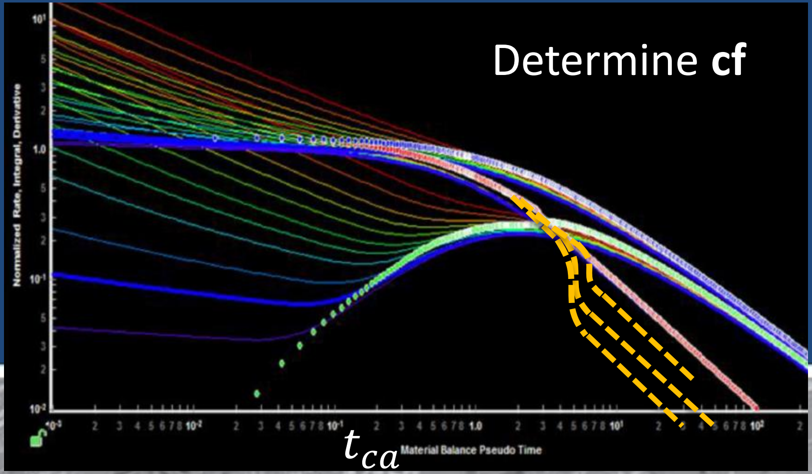
RTA in geopressured reservoirs:

A. Correction of material balance pseudo-time (tca)

$$t_{ca} = \frac{G C_{ti}}{q_g}\left(P_{a_i} - \overline{P_a}\right)$$

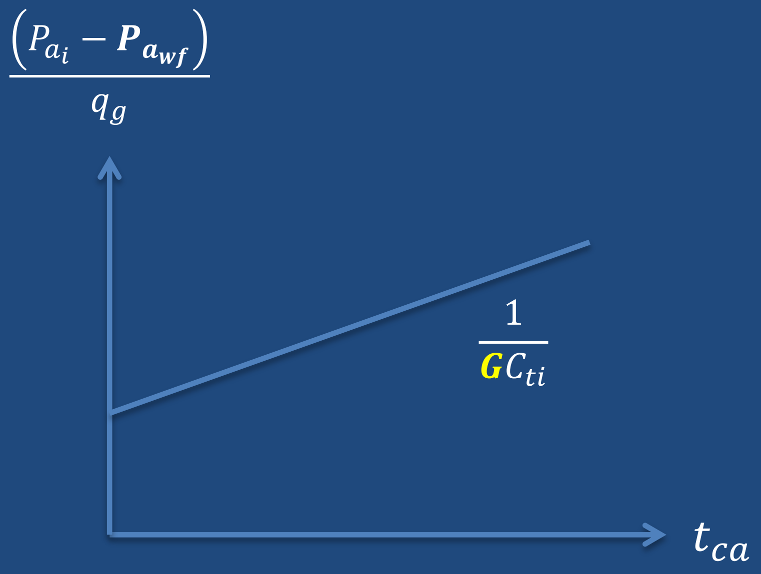
$$\frac{\overline{P}}{\overline{z}} = \frac{P_i}{z_i}\left(1 - \frac{G_p}{G}\right)$$

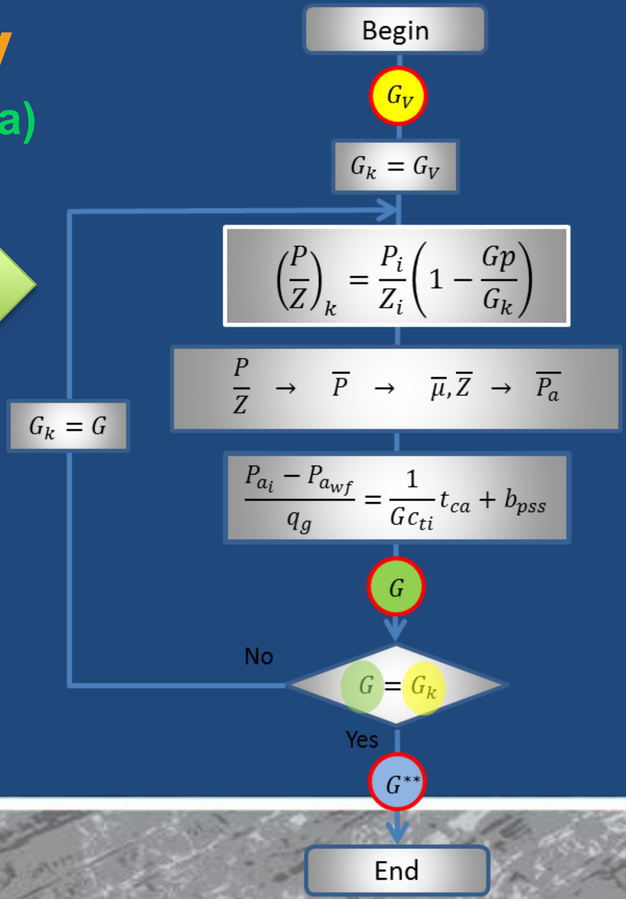
B. Solve the diffusivity equation and generate a new type curve family



Methodology

A. Correction of material balance pseudo-time (tca)





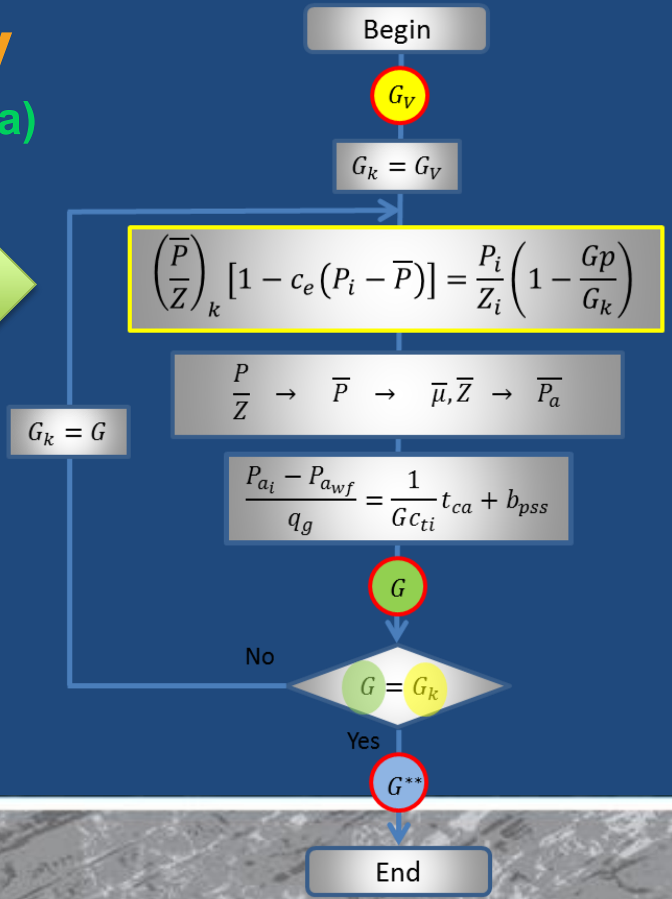
Methodology

A. Correction of material balance pseudo-time (tca)

$$\frac{\overline{P}}{\overline{Z}}[1 - c_e \Delta P] = \frac{P_i}{Z_i}\left(1 - \frac{G_p}{G}\right)$$

$$c_e = \frac{c_w S_w + c_r}{(1 - S_{wi})}$$

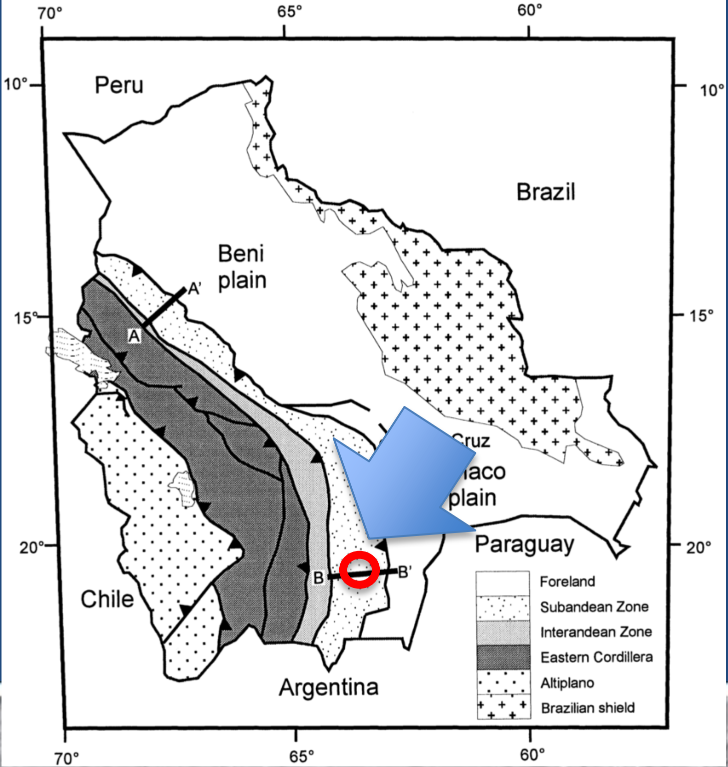
$$c_e = \frac{c_w S_w}{(1 - S_{wi})} + \frac{(c_m + c_f)}{(1 - S_{wi})}$$



Case Study

General Information Caigua Field

Santa Rosa Reservoir	
Initial Pressure, Pi	4474 psia
Reservoir Temperature, Tr	185 °F
Depth, h	2200 m
Pore pressure gradient, Grad.	**0.62 psi/ft**
Porosity,	0.06
Water Saturation, Sw	0.47



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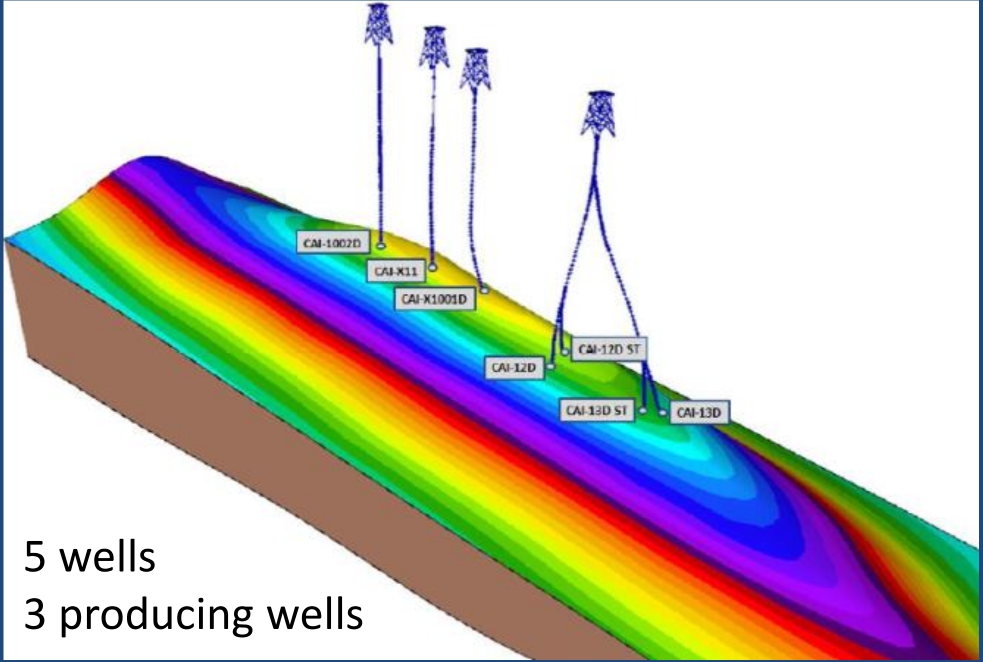


Case Study

General Information Caigua Field

Fluid Properties	
Gas Specific Gravity, SGg	0.61
Molar percent of CO2,	2.7%
Water-Gas Ratio, WGR	0 STB/MMscf
Condensate-Gas Ratio, CGR	0.3 STB/MMscf

Laboratory/Logs:

Cf m = 2.5E-4 psi^-1

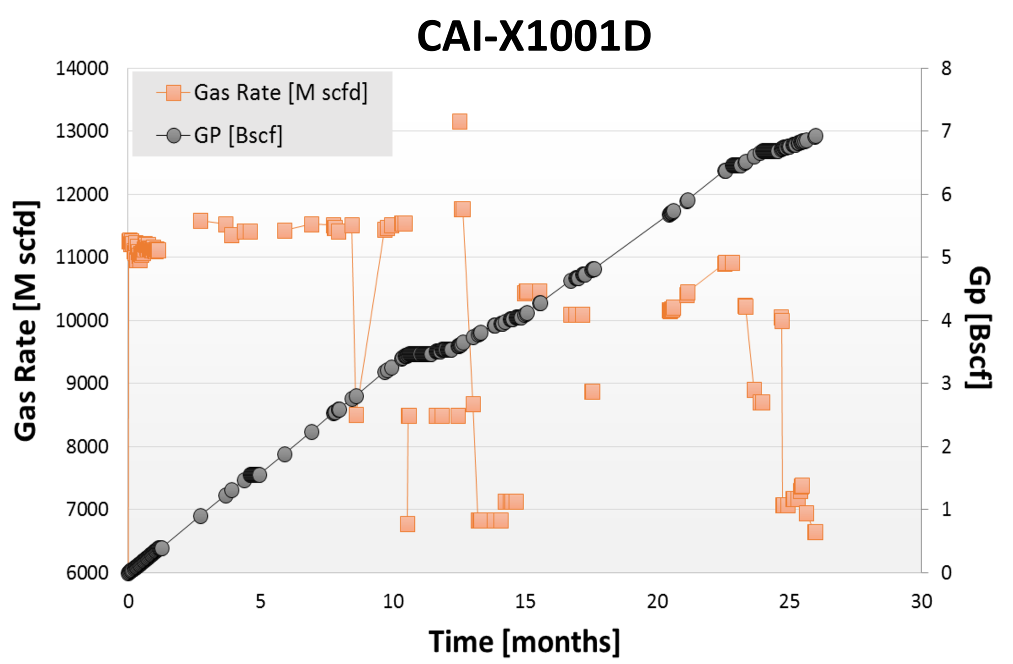
Ø m = 0.055

Ø f = 0.005

Well Testing:

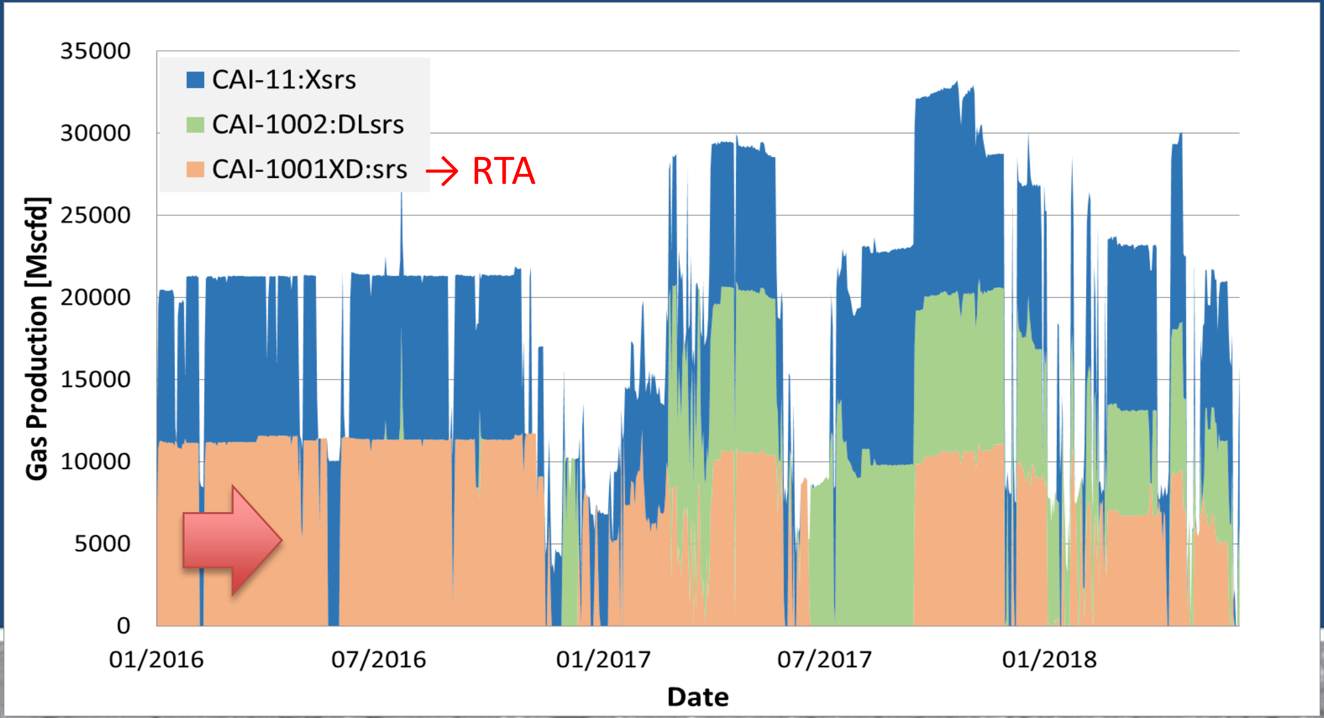
Cf f = 6.5E-4 psi^-1

(Tiab)



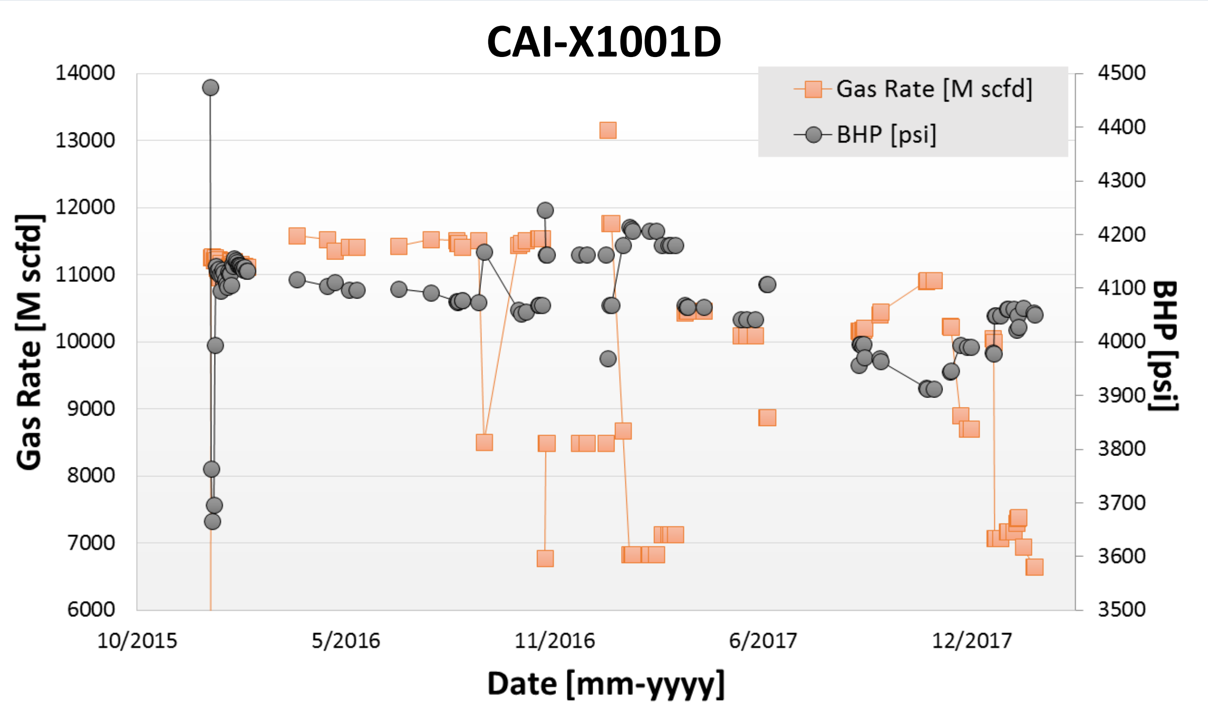
Case Study

Production distribution history



Case Study

Production Test

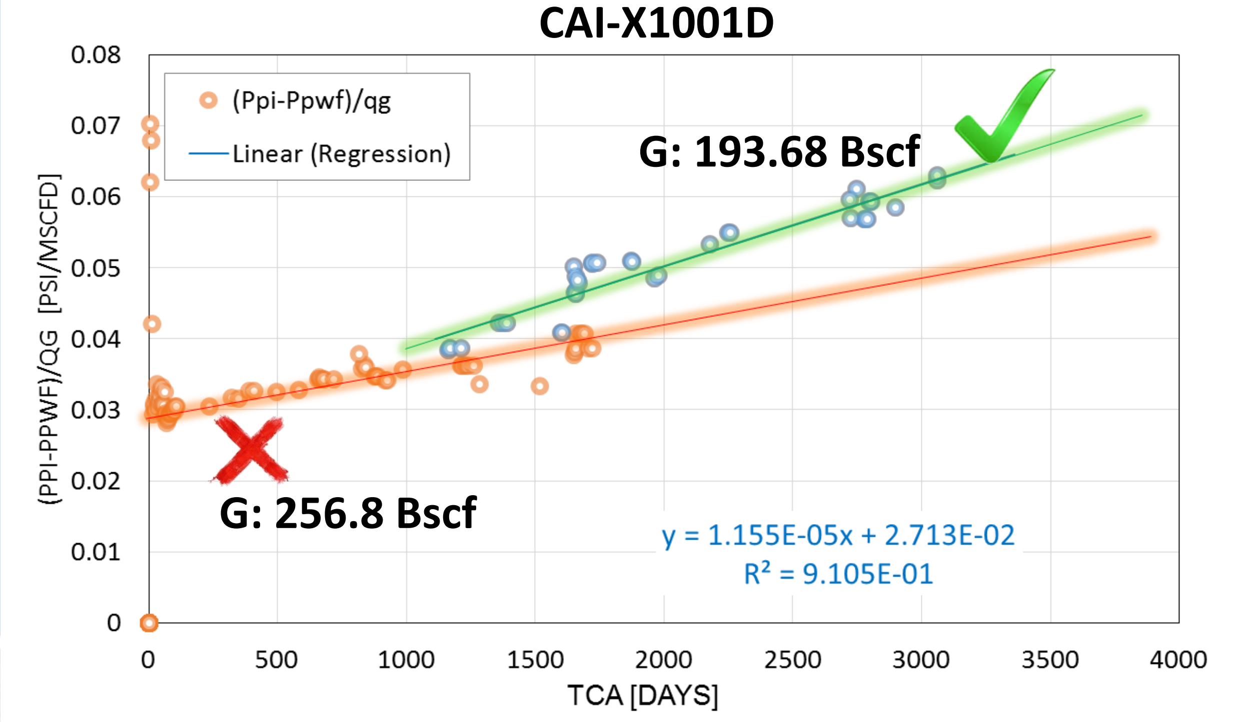


RESULTS

Dynamic Material Balance

(Normal Pressure)

$$\frac{P}{z} = \frac{P_i}{z_i}\left(1 - \frac{G_p}{G}\right)$$



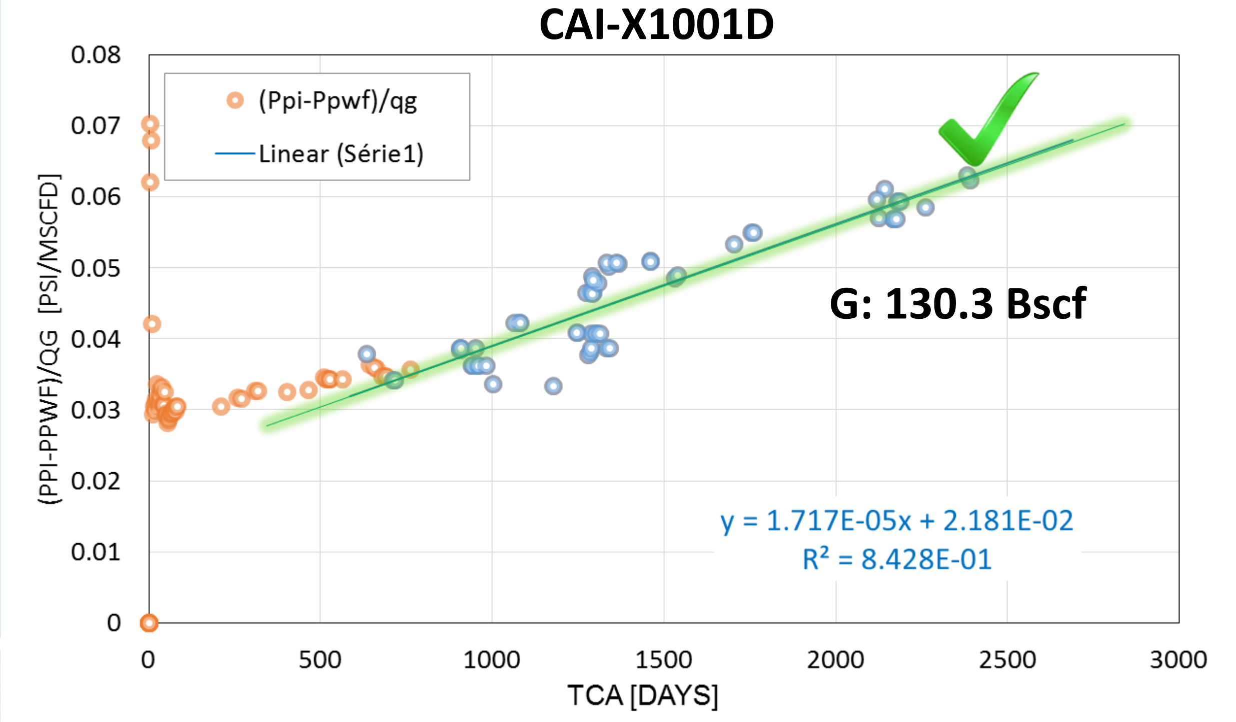
Ct i = 6.93E-4 psi^-1

RESULTS

Dynamic Material Balance

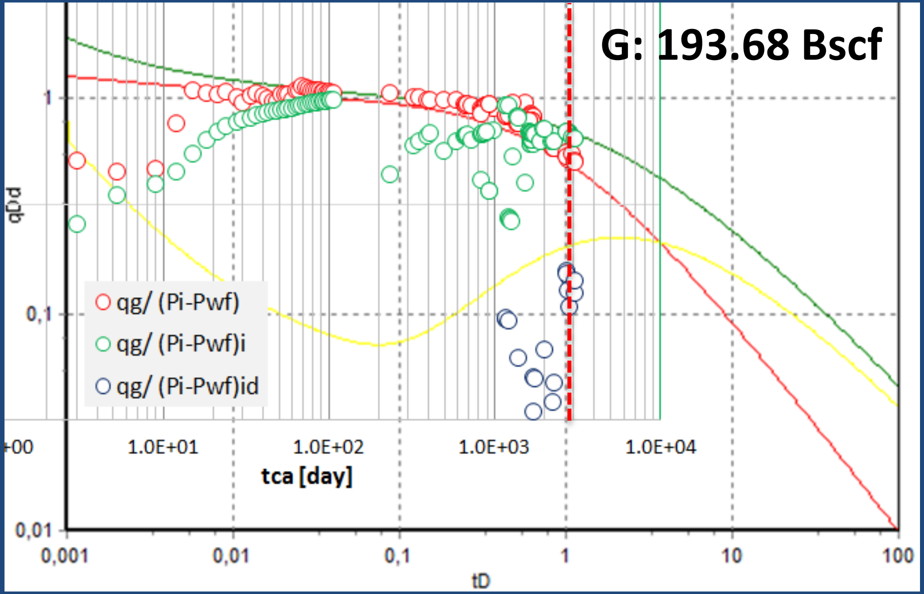
(Abnormal Pressure)

$$\frac{P}{z}[1 - c_e \Delta P] = \frac{P_i}{z_i}\left(1 - \frac{G_p}{G}\right)$$

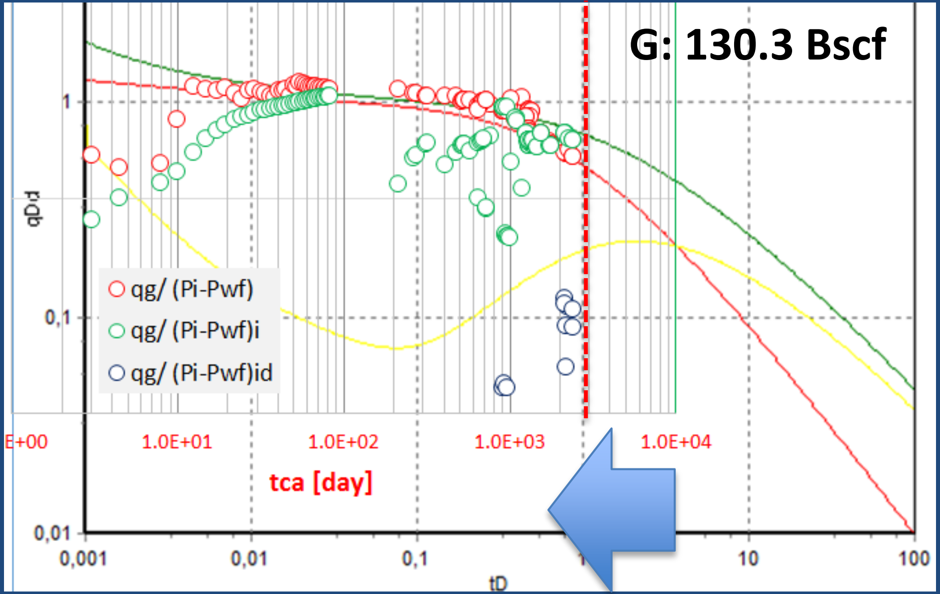


RESULTS

Normal pressured



Abnormal pressured



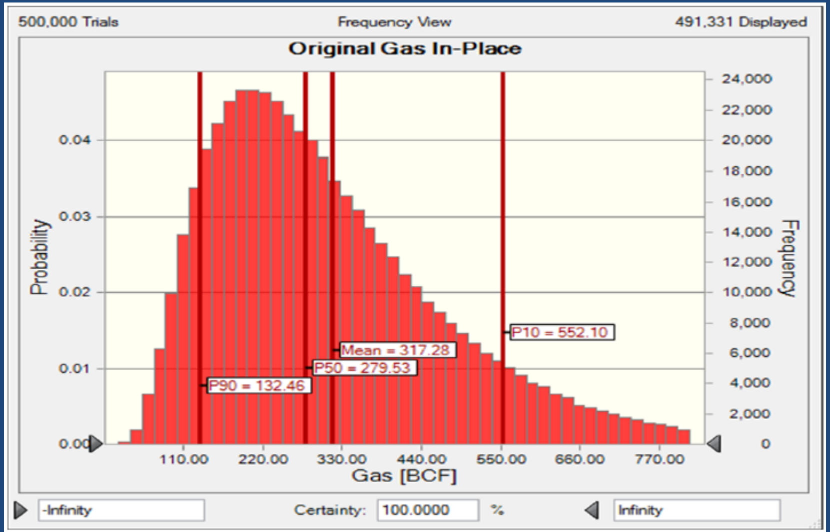
RESULTS

Results of Monte Carlo Simulation

- Santa Rosa:

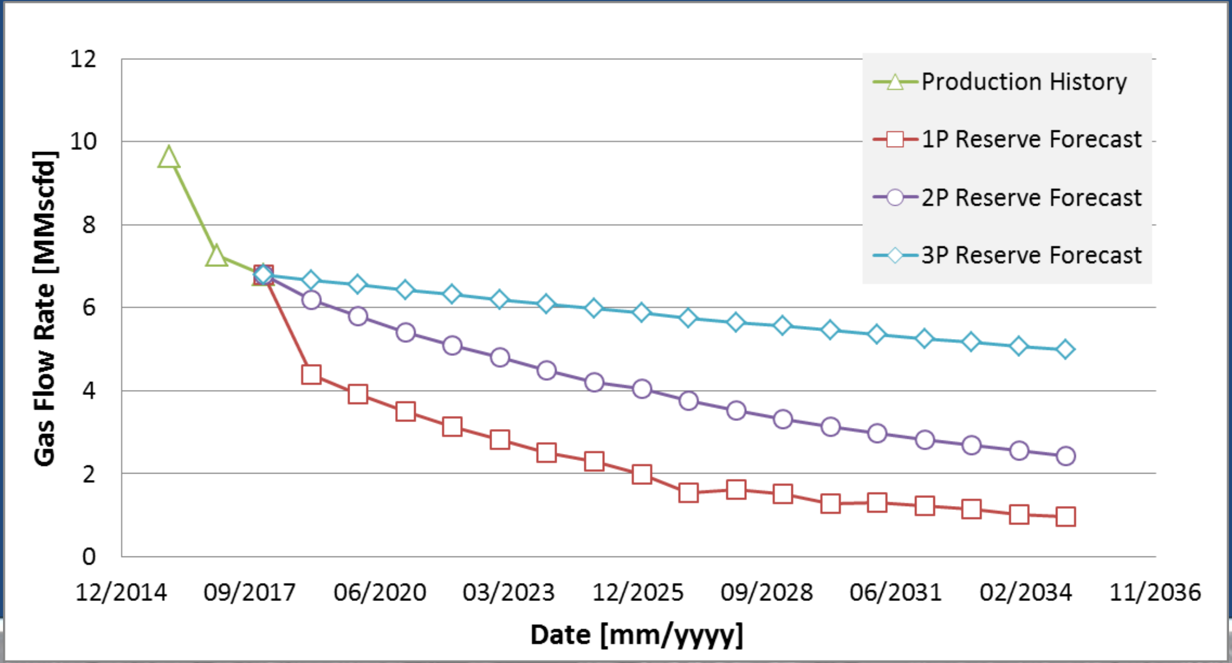
	Total OGIP [Bscf]	OGIP CAI-X1001 [Bscf]
1P	132.5	**54.3**
2P	279.5	**114.6**
3P	552.1	**226.4**

OGIP RTA: 130.3 Bscf (CAI-X1001)



RESULTS

Production Forecast



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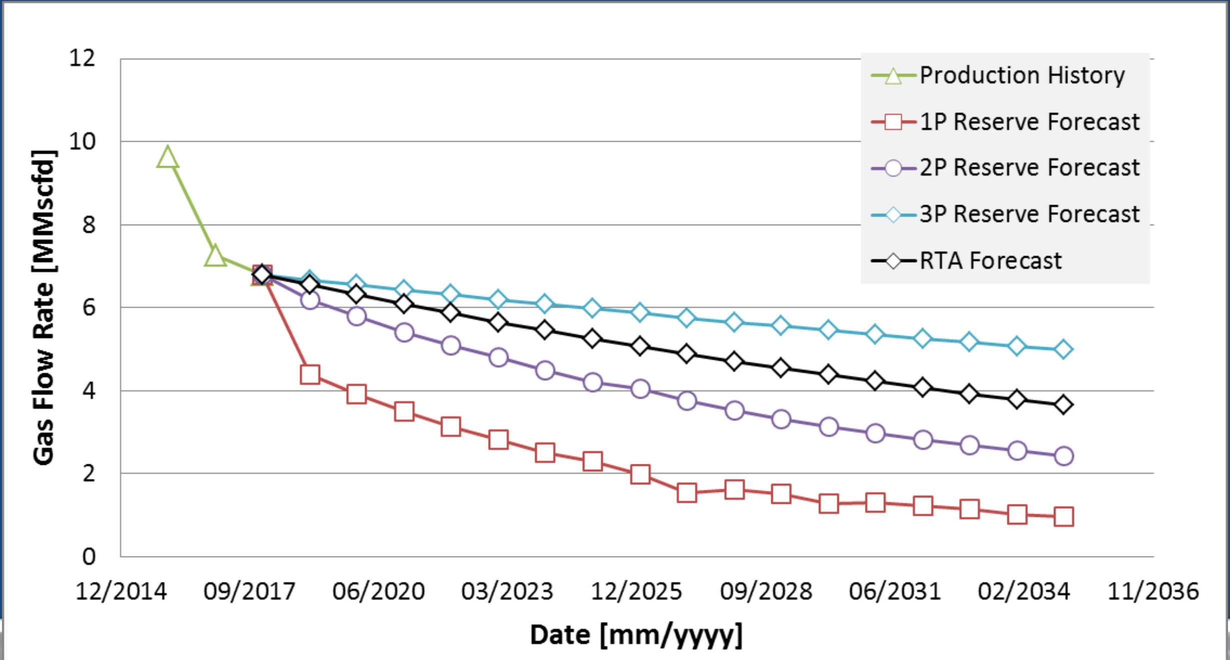

Conclusions

- Rate Transient Analysis must be carefully applied in over-pressured reservoirs to avoid over-estimation of hydrocarbon reserves.
- Effective rock compressibility can be included in the material balance equation to correct the computation of “material balance pseudo-time”.
- Modified dynamic material balance equation can provide a reliable production forecast specially for reservoirs with few production history.
- The application of rate transient analysis is an alternative method to validate the conventional volumetric method in geopressured gas reservoirs.