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Proxy Models: Unconventional Gas Forecasting & Reserves Analysis

Introduction

Currently, there is an assortment of reservoir analysis methods ranging from traditional decline and type-curve matching to rate-pressure polynomials and detailed rate-pressure simulation. Yet, despite its many limitations, conventional decline analysis is still commonly used in gas (and oil) production analysis for onshore due it minimal data requirements and the obvious ease of application - regardless of the desire for more sophisticated methods

The "Buba" or "BK" Identity

Muhammad Buba & Knowles presented a summary of semi-analytic identities and plotting functions which can be used to extrapolate or estimate OGIP using only production data (q_g and G_p) without a prior knowledge of formation and/or fluid compressibility, or even average reservoir pressure.

Re-arrangement of this identity results in direct estimation of OGIP if linked to Arps decline through q_{gi}

The Workflow & Procedure

An evaluation of the BK model shows that it can be re-arranged for a rapid evaluation of OGIP without deviating significantly from Arps decline method. The analyst solely adjusts the initial decline rate (q_{gi}) of the Arps decline, which is used by the BK model to provide OGIP as a function of time.

The procedure can be modified to produce either actual (or effective) reservoir perm. for rate forecasting.

1

$$q_g = q_{gi} - \frac{2q_{gi}}{\left[1-\left[\frac{P_{wf}/z_{wf}}{P_i/z_i}\right]^2\right]OGIP}G_p + \frac{q_{gi}}{\left[1-\left[\frac{P_{wf}/z_{wf}}{P_i/z_i}\right]^2\right]OGIP^2}G_p^2$$

2

$$OGIP = \frac{\boxed{\frac{1}{2}}\left(2\eta \pm 2\cdot(\eta^2+\eta\cdot q_g-\eta\cdot q_{gi})^{\frac{1}{2}}\right)G_p}{(q_{gi}-q_g)}$$

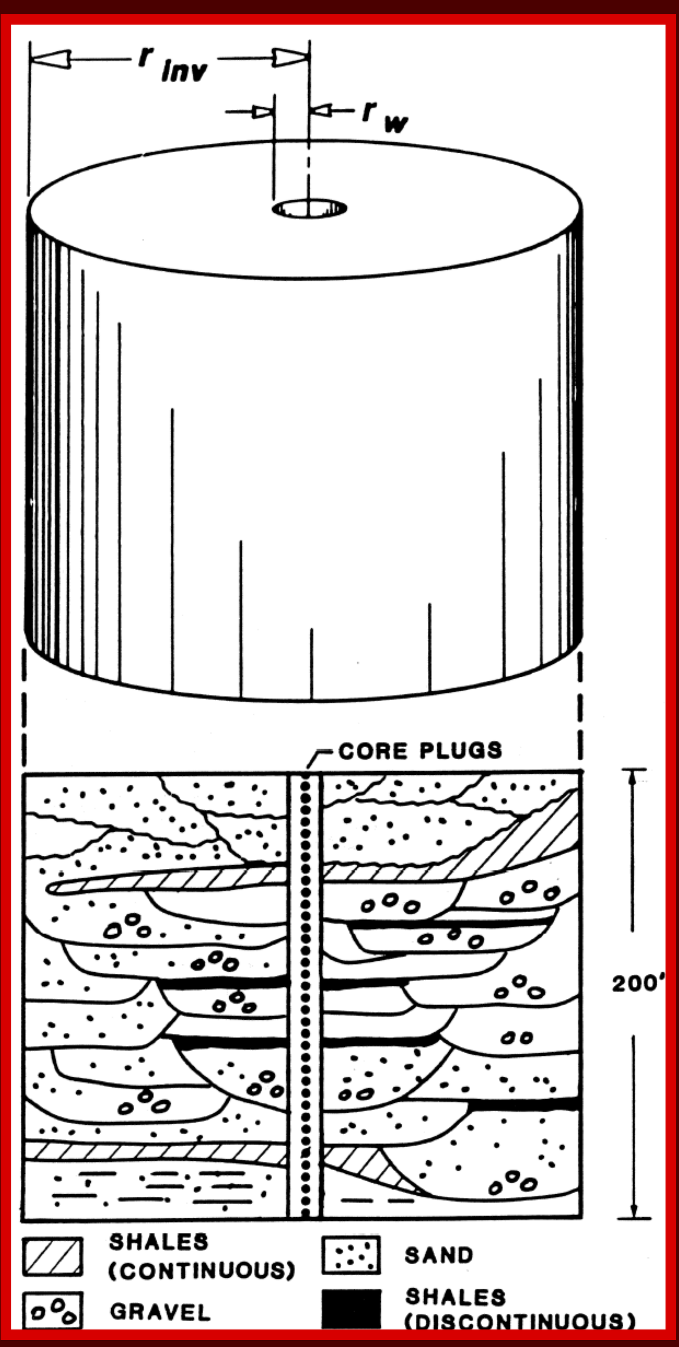
Constant Changes to 10/12 for CBM/ Shale Reservoirs with Absorbed Gas

3

$$q_g = \frac{q_{gi}}{(1+b\cdot Dt)^{1/b}}$$

4

$$k = \frac{q_g(1.417\times10^6)\bar{\mu}T_f\left[\frac{1}{2}\ln\left[\frac{4A}{e^{\gamma}C_A r_w^2}\right]\right]}{h\left(\left(\frac{P_r}{z_r}\right)^2-\left(\frac{P_{wf}}{z_{wf}}\right)^2\right)}$$

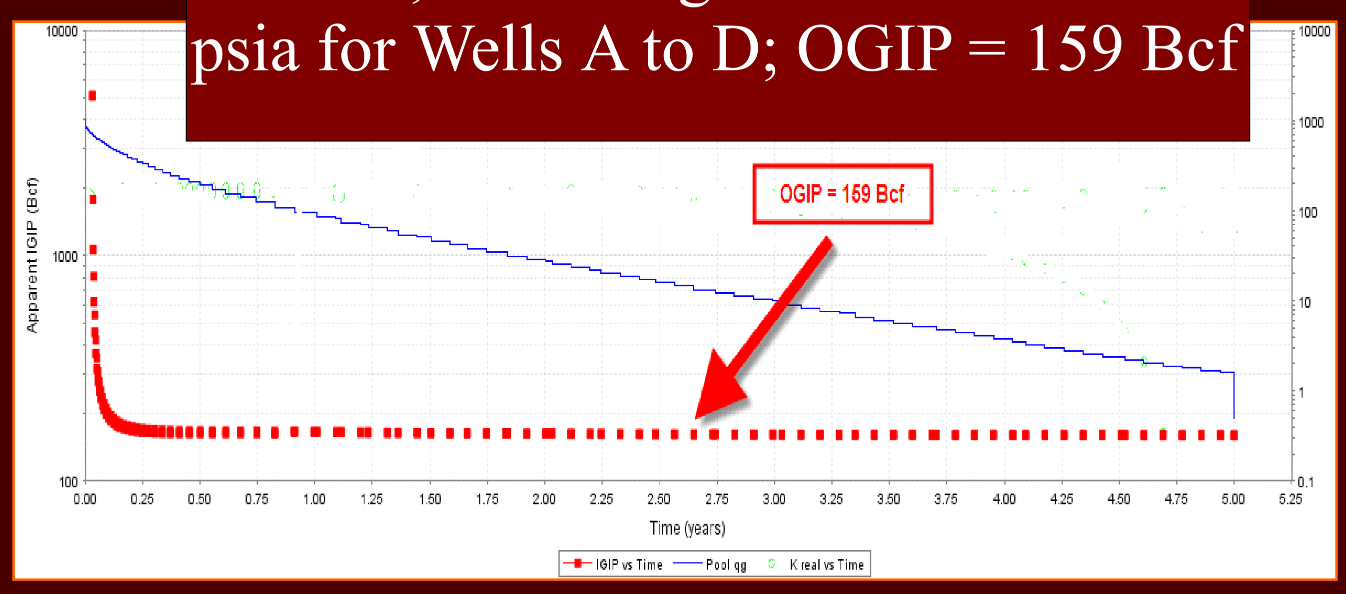


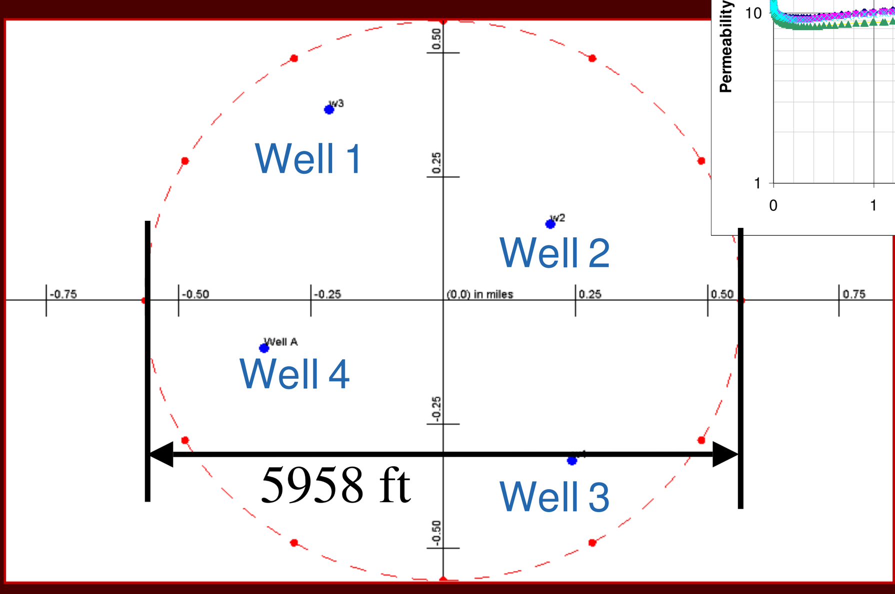
The BK Model Converts Random Heterogeneity and Arbitrarily Shaped Reservoirs into an Equivalent Radial Homogeneous Reservoir

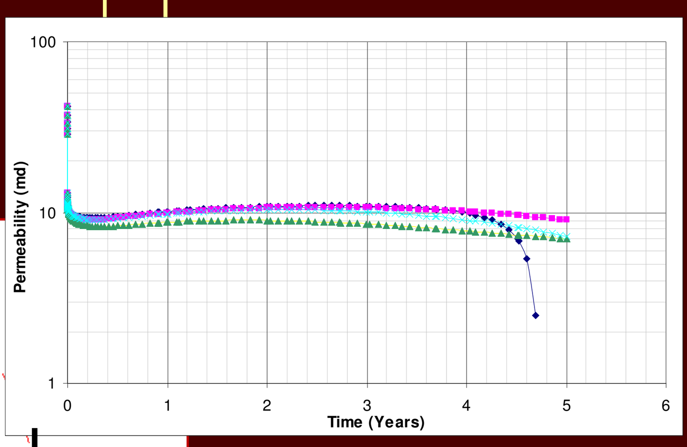
Adaptation for Pool Analysis

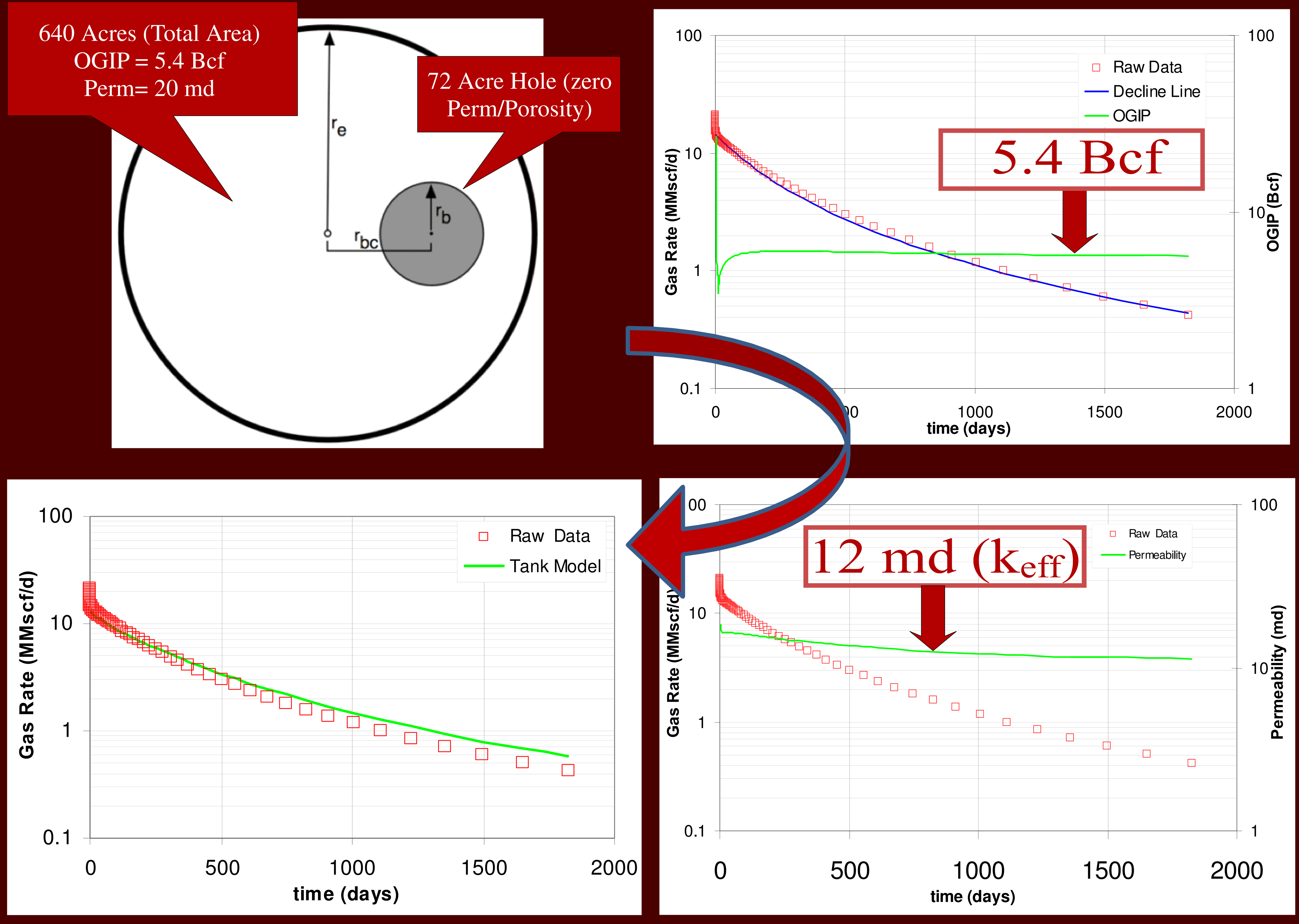
$$q_{g,pool} = q_{gi,pool} - \frac{2q_{gi,pool}}{\left[1-\left[\frac{P_{wf,well}/z_{wf,well}}{P_i/z_i}\right]^2\right]OGIP}G_{p,pool} + \frac{q_{gi,pool}}{\left[1-\left[\frac{P_{wf,well}/z_{wf,well}}{P_i/z_i}\right]^2\right]OGIP^2}G_{p,pool}^2$$

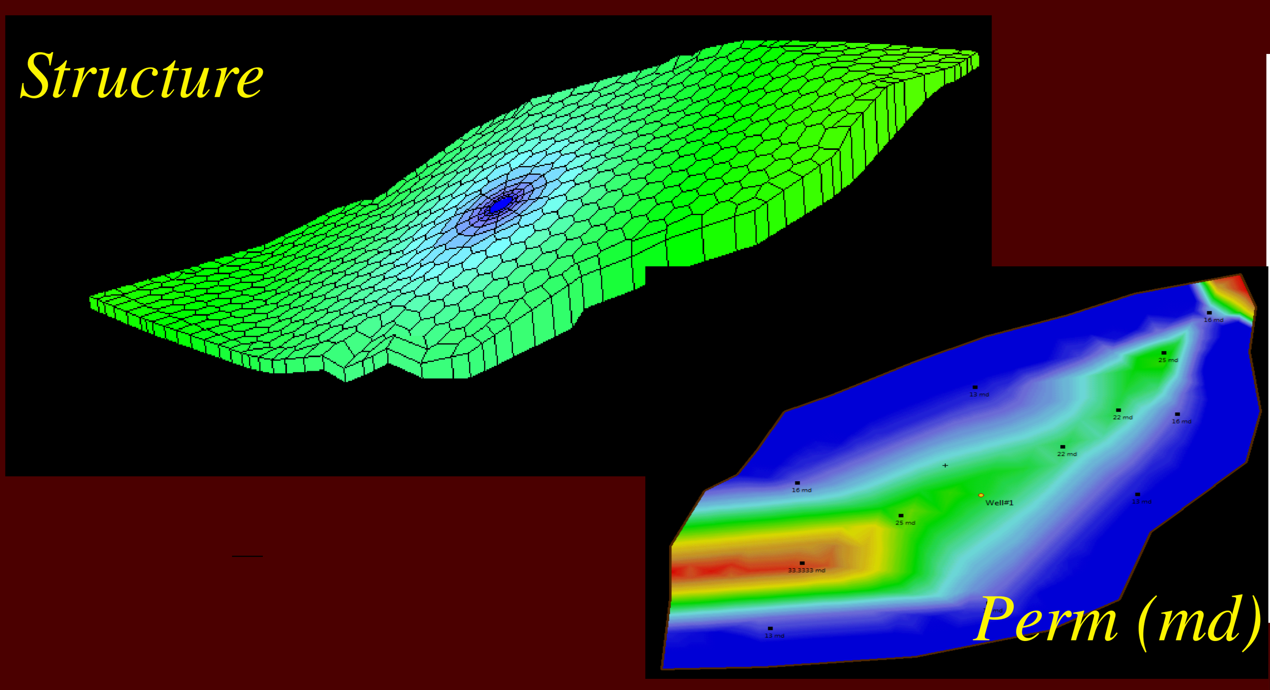
10 md; Pwf Ranges from 980-1025 psia for Wells A to D; OGIP = 159 Bcf

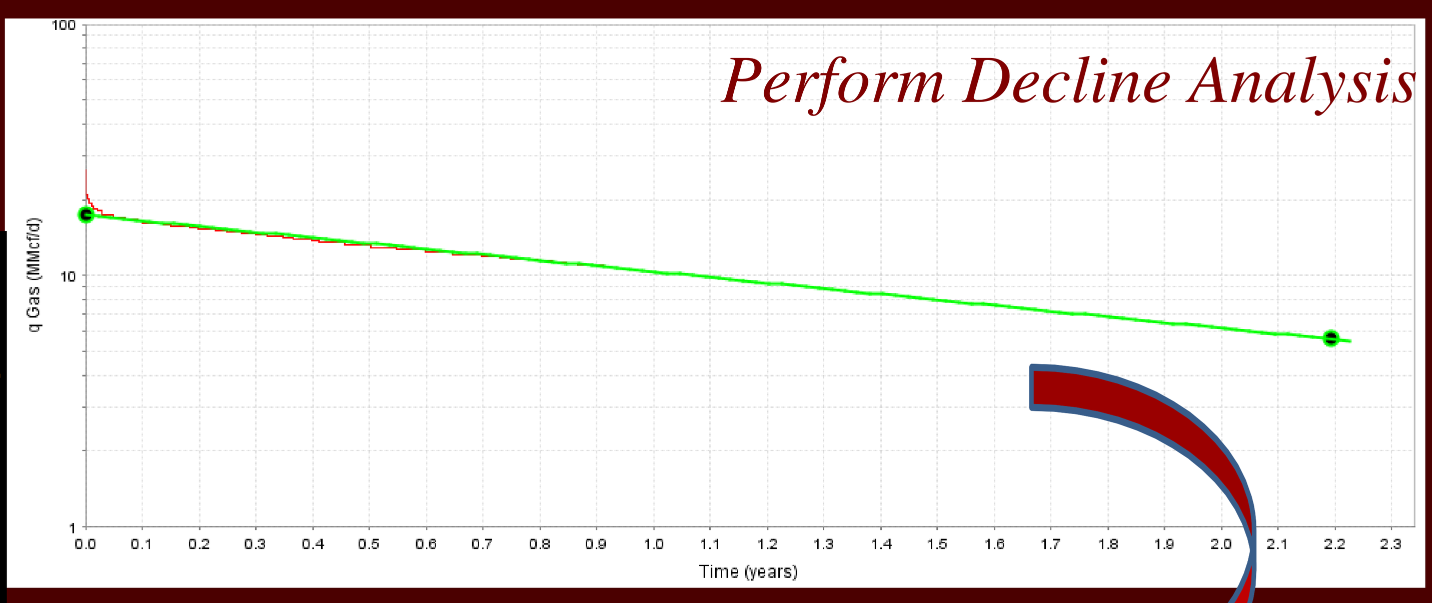


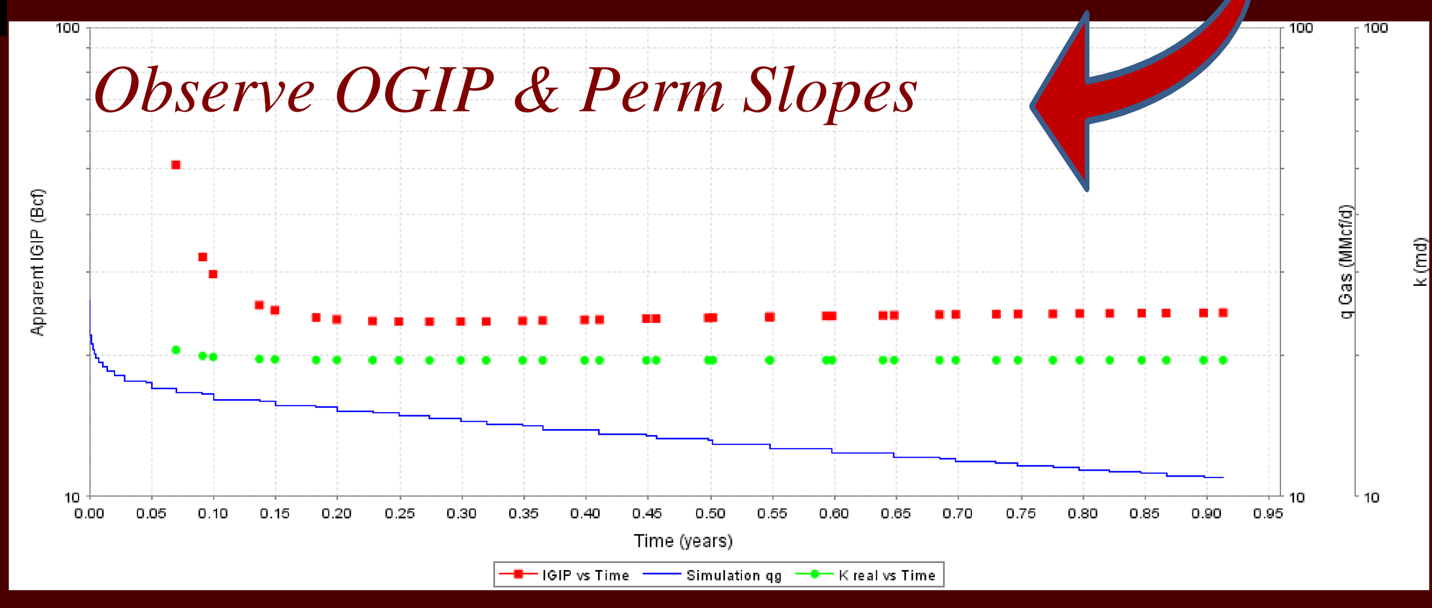








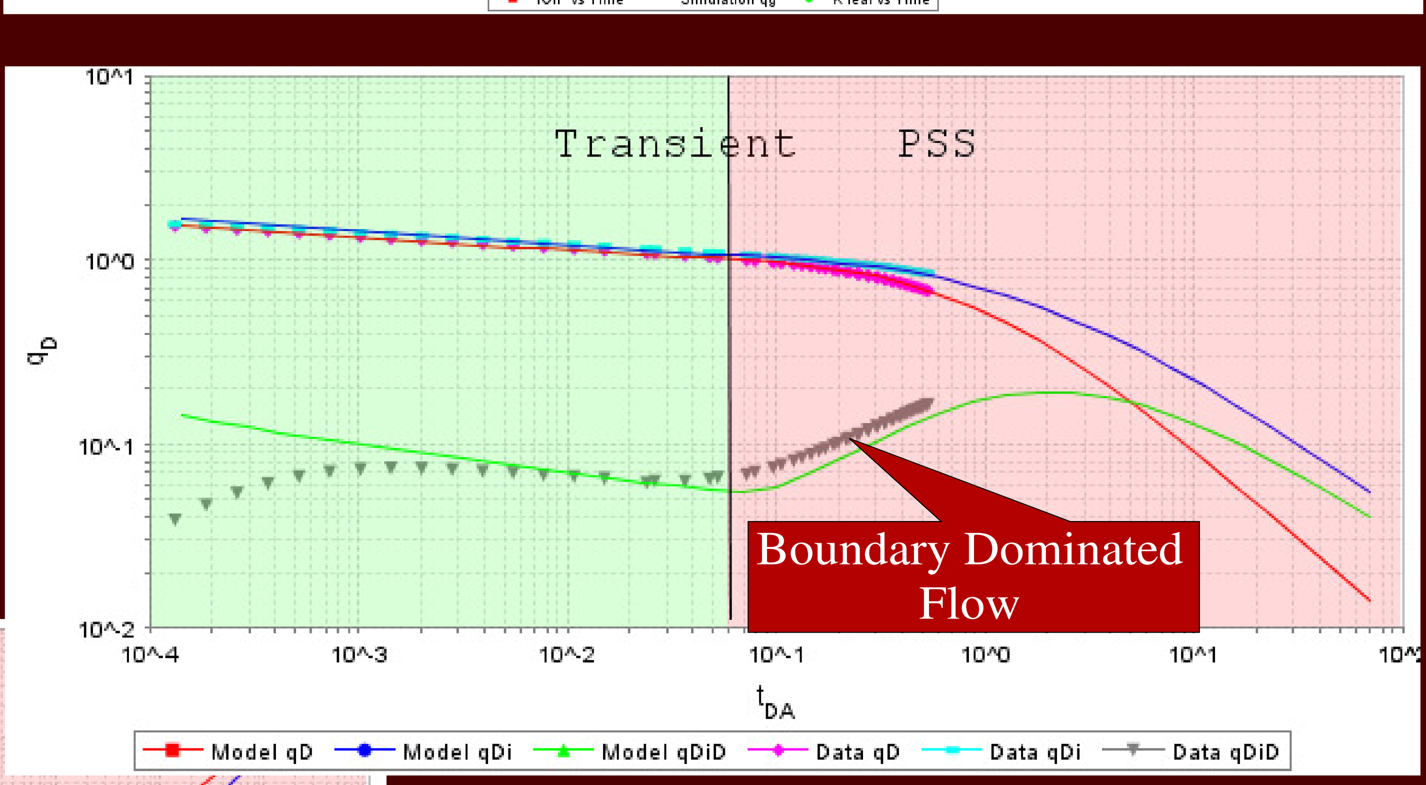


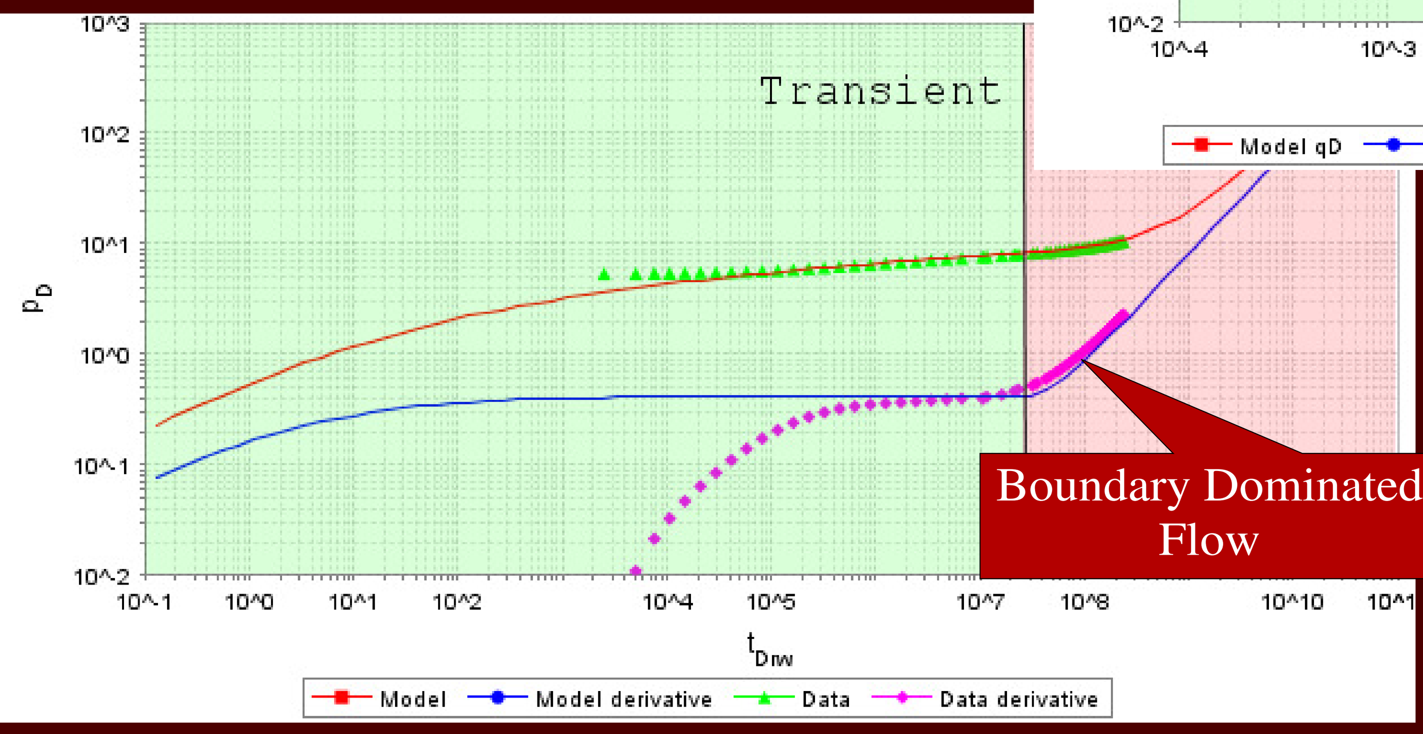


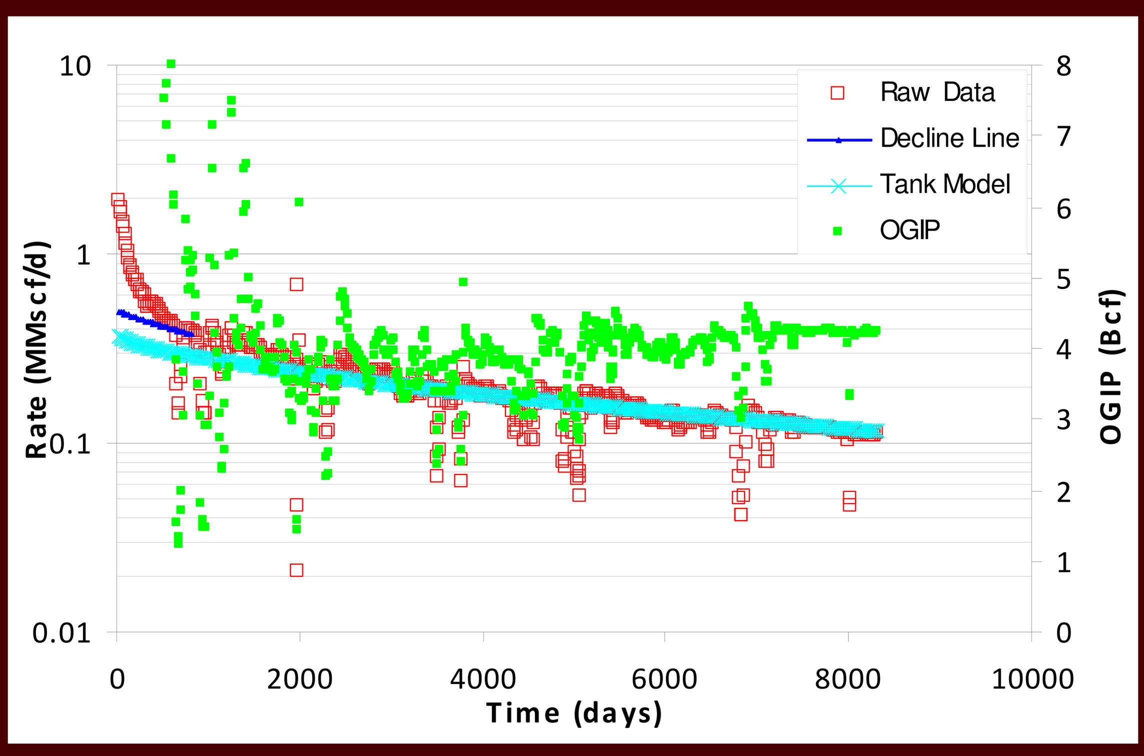
Simulated Example with Structure & Permeability Variation.

Net pay varies from 9 to 32 m (30 to 100 ft), based on 13 nodes with an average thickness of 19 ft. Permeability varies from 13 to 33 md (12 nodes), also with an average of 19 md. Zone top varied by 128 m (420 ft).

Flowing material balance analysis indicated OGIP to be 23.5 Bcf which is confirmed by the BK Diagnostic. Blasingame and Bourdet type curves confirmed that the effective reservoir model provided suitable long-term production forecast







Tight Gas Well J7

The BK model provided an initial OGIP of approx. 4.1 Bcf (which is slightly lower than reported results) with an effective permeability of 0.005-0.007 md, and average drainage area of 40-48 Acres. Simulation work suggested an OGIP of 6.9 - 7.1 Bcf with a variety of interpretations including linear homogeneous closed reservoir and radial dual porosity closed reservoir.

Barnett Shale Gas Well

Original data was analysed using PROMAT with an approx. Perm 0.005 md (x_f=130/150 ft), and OGIP/ drainage area to be 1.1 Bcf and 24.5 Acres respectively.

The BK Model also provided an OGIP of 1.1, and an effective permeability of 0.02 md. The permeability is high compared to the results from the PROMAT model. The BK model represents the combined effect of matrix and fracture.