

Ramp effect

Patrick Corbett
Hamidreza Hamdi
Hemant Gurav

Outline

- **Definition of ramp**
- **Derivative examples resembling ramp**
- **Interpretation of ramp**
 - **Statistical interpretation of ramp**
 - **Analytical-Numerical interpretation of ramp**
 - **Numerical interpretation of ramp**
- **Case studies**
- **Conclusions**

Definition

- **What is the Ramp effect?**

Simply it is a monotonic increase in the derivative curves over an order of magnitude

- **Why it is important?**

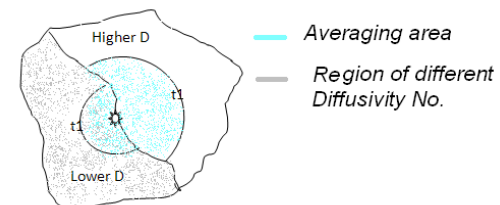
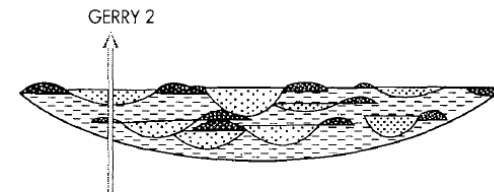
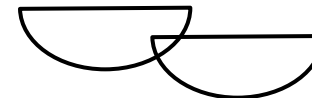
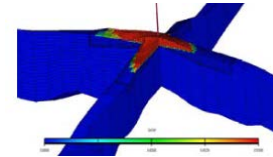
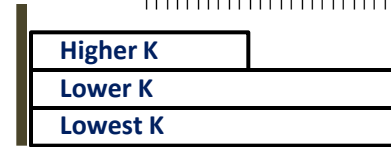
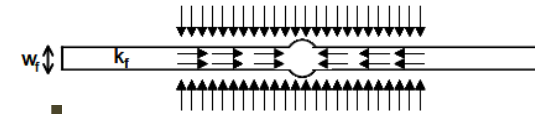
Well test modelling is an inverse problem : several models are frequently applicable to describe the test response. Knowing the physics behind the test response help correctly describe the test response. This also help in development plan, decision making and reservoir management.

- **There are several cases with rapid rise of derivative, so what's new?**

1. It's a geological areal micro-cross flow phenomenon
2. Better reservoir characterization
3. Not to match any response with some inappropriate models

Derivative rise-Examples

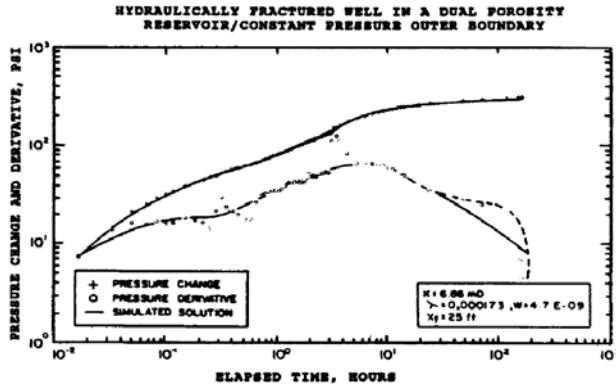
- Hydraulic fracture reservoirs →
- Layered reservoirs- differential depletion →
- Gas reservoir with WOC →
- Geo-choke (transient ramp) Less than an order of magnitude →
- Channel belt – channelized reservoir →
- Loss of connectivity (and/or Ramp) →
 - Correlation length
 - Vertical permeability
 - Areal permeability contrast
 - Heterogeneity size



Derivative rise-Examples

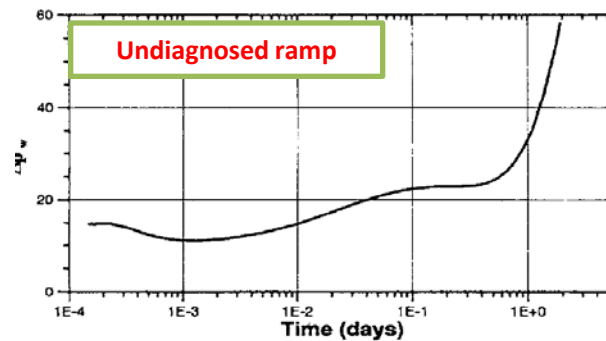
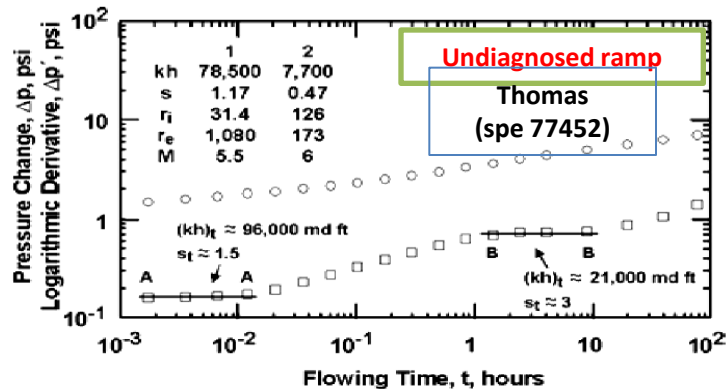
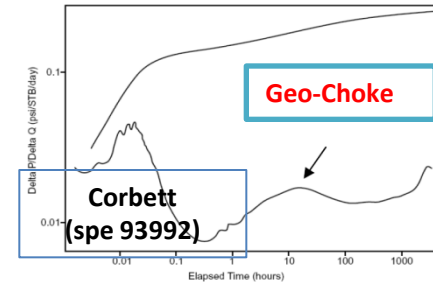
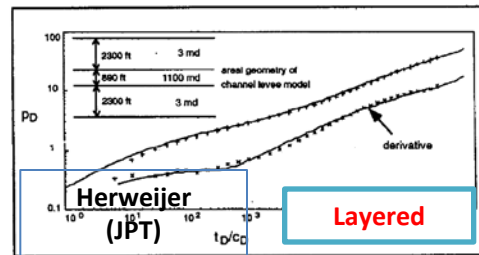
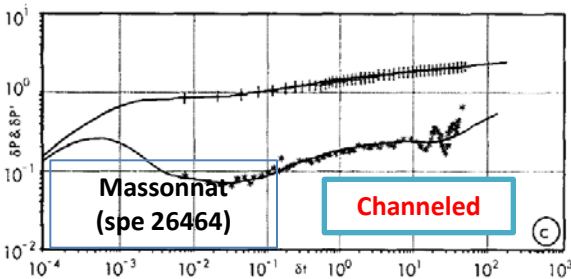
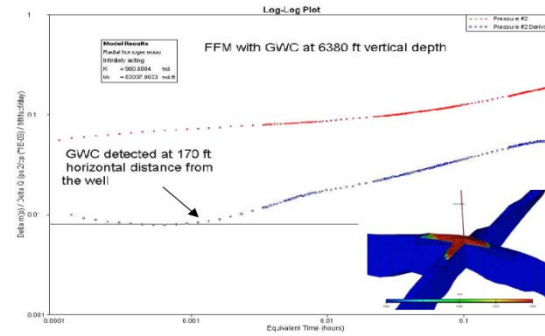
Hydraulic fracturing

Alvarado (spe 23687)



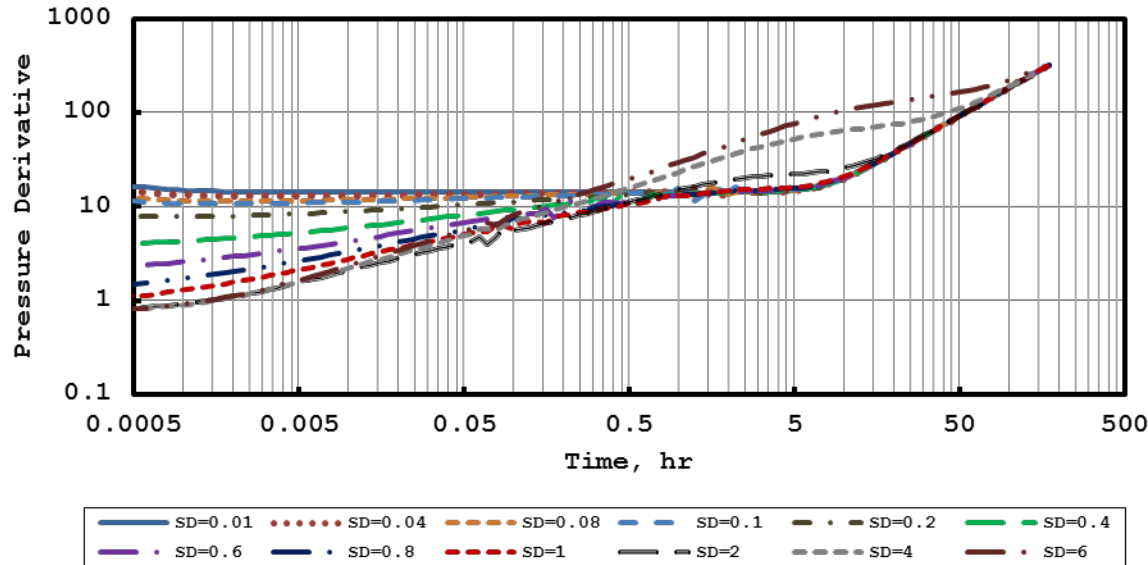
Anticlinal gas reservoir

Dahrough (spe 94446)



- statistical Interpretation of Ramp

Effect of Standard Deviation on The Pressure Derivative



$$1. \quad \frac{K_{eff}}{K_G} = \exp \left[\left(\frac{1}{2} - \frac{1}{D} \right) \sigma_Y^2 \right]$$

$$2. \quad \frac{K_{eff}}{K_G} = 1 + \sigma_Y^2 \left[\frac{1}{2} - \frac{1}{D} + \frac{\beta(t)}{D} \right]$$

$$\beta(t) = \frac{1}{\sigma_Y^2} \int C_Y(|\mathbf{x} - \mathbf{x}'|) G(\mathbf{x}, \mathbf{x}', t) d\mathbf{x}'$$

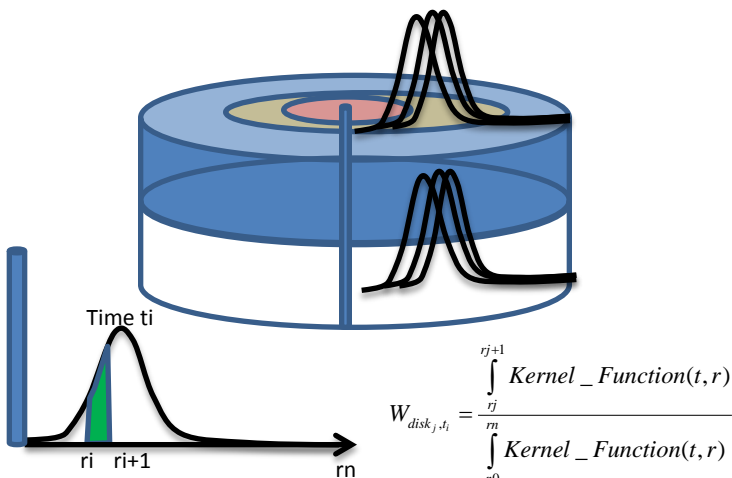
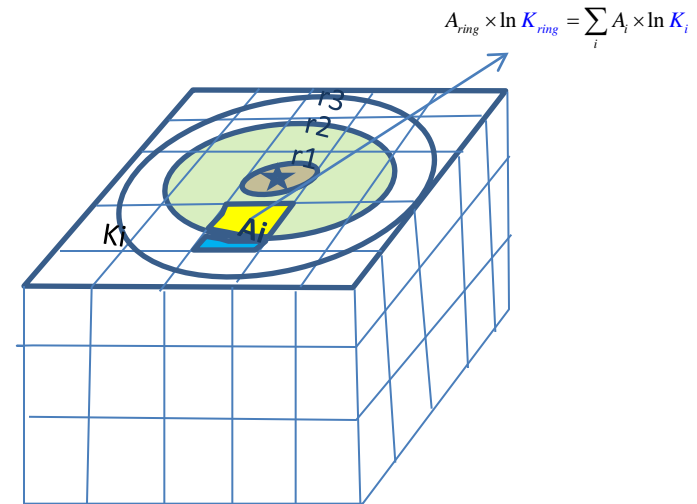
$$\frac{K_{eff}}{K_G} = 1 + \sigma_Y^2 \left[\frac{1}{2} \right] \approx \exp \left(\frac{\sigma_Y^2}{2} \right) \equiv \text{arithmetic average when } (t \rightarrow 0)$$

$$\frac{K_{eff}}{K_G} = 1 + \sigma_Y^2 \left[\frac{1}{2} - \frac{1}{D} \right] \approx 1 \equiv \text{geometric average when } (t \rightarrow \infty, D)$$

- Analytical-Numerical Interpretation of Ramp

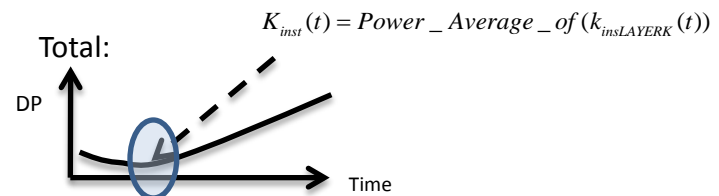
Analytical-Numerical combination

- Create a model with Log-normal distr.
 - $\Delta x = \Delta y = 10\text{ft.}$ ($2000\text{ft} \times 2000\text{ft} \times 25\text{ft}^3$)
 - Follow the methodology described here
 - Calculate the analytical Kinst (Feitosa 1994)
 - Plot both kinst (Numerical and Analytical)
- Results:**
Can be used in well test history matching to skip simulation 😊

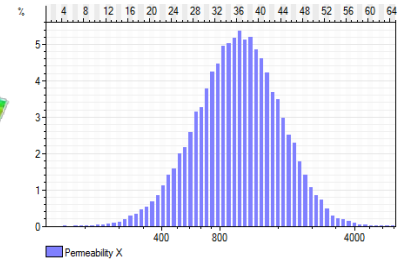
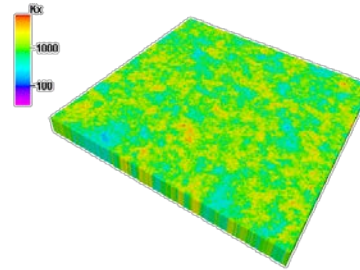
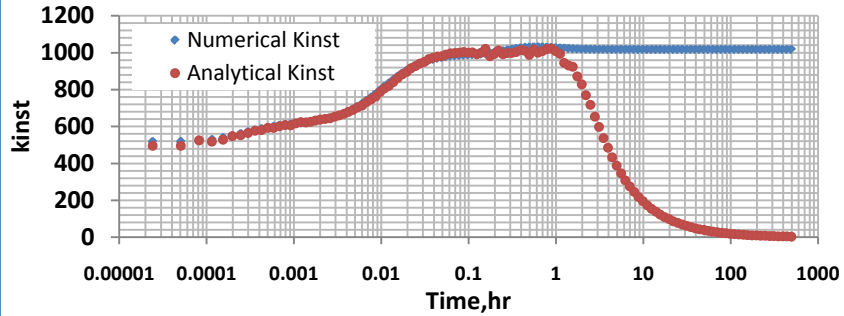


Layer 1: $\frac{1}{k_{inst}(t)} = \sum_{disk=j} W_{j,t} \times \frac{1}{k_{ringj}}$

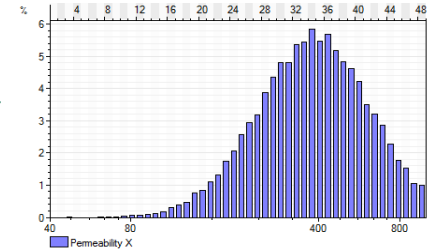
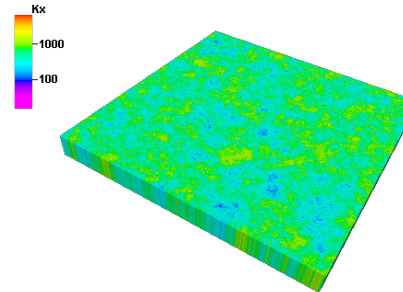
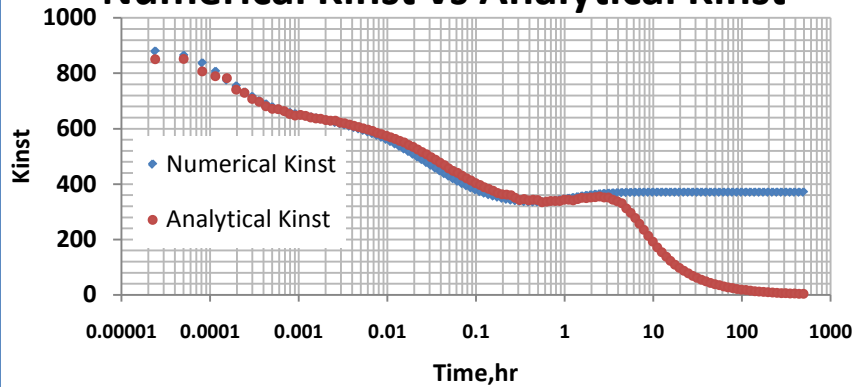
Layer 2: $\frac{1}{k_{inst}(t)} = \sum_j W_{j,t} \times \frac{1}{k_{ringj}}$

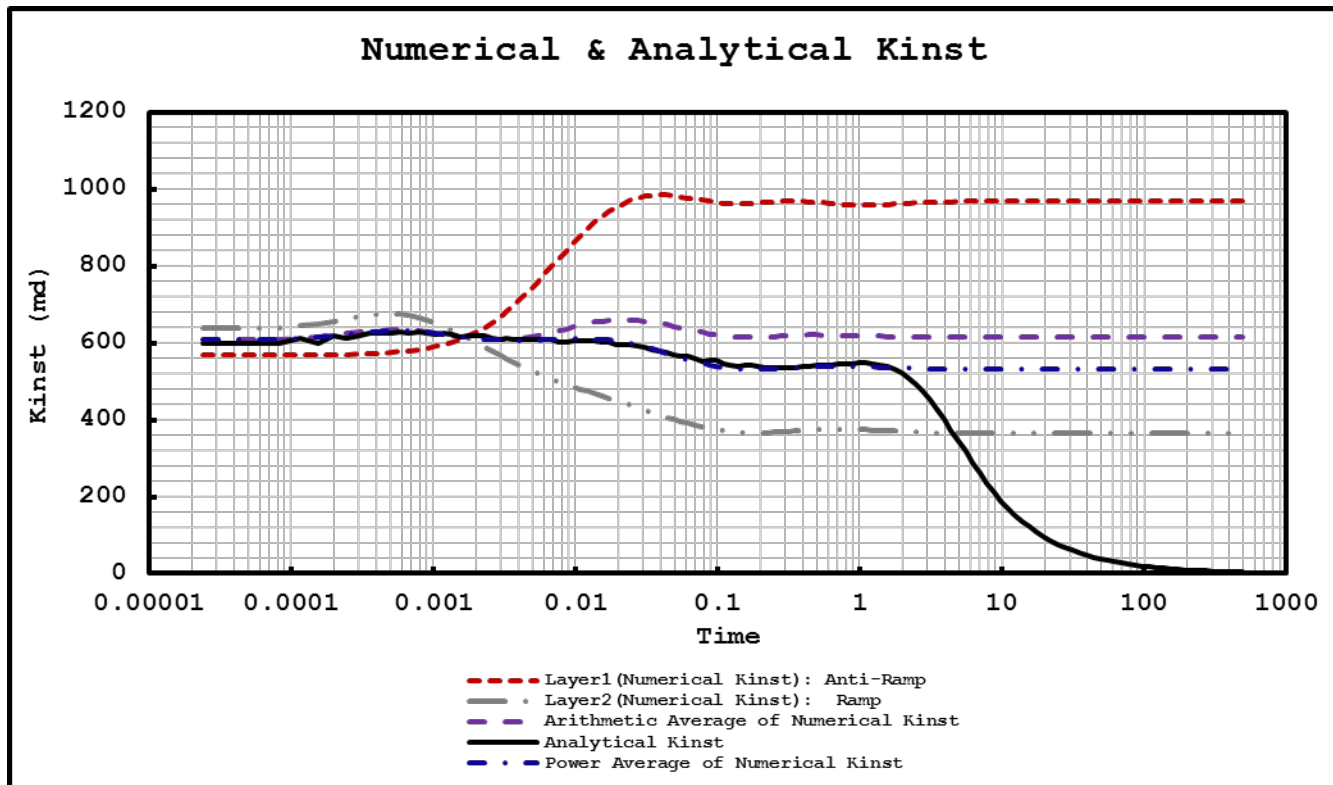


Numerical Kinst vs Analytical Kinst



Numerical Kinst vs Analytical Kinst

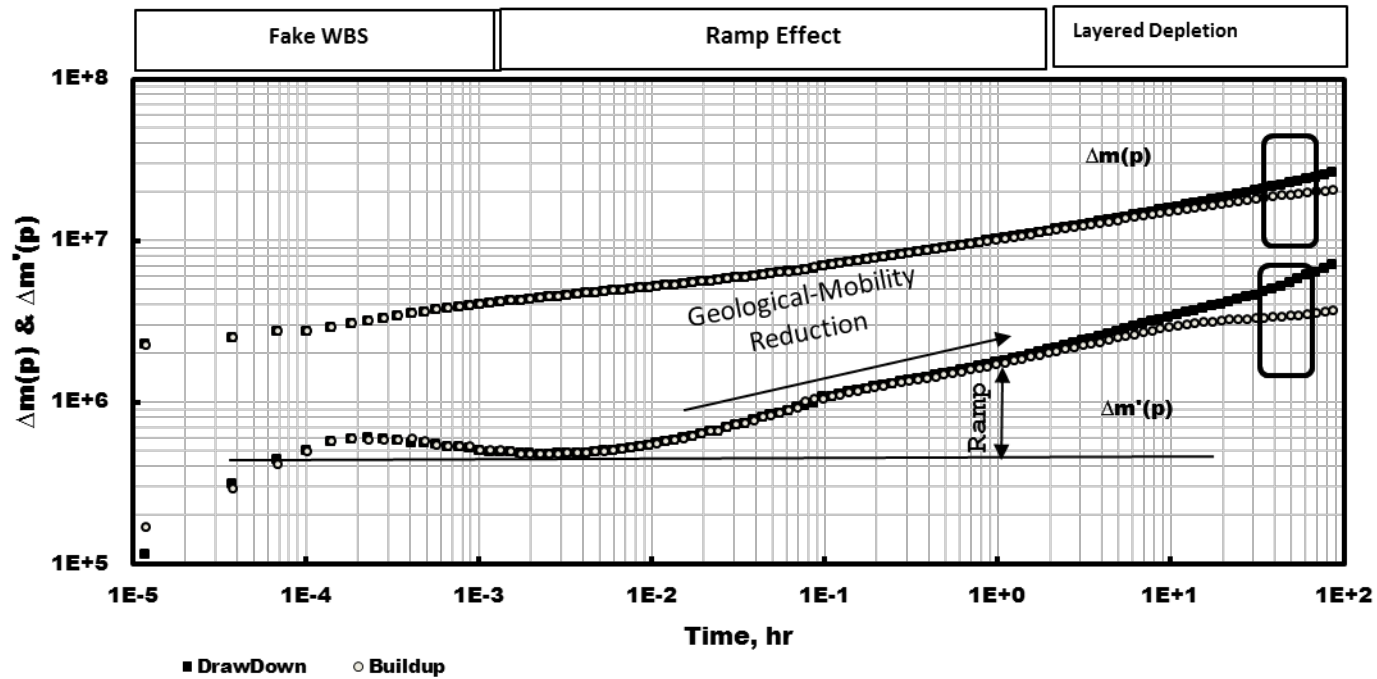




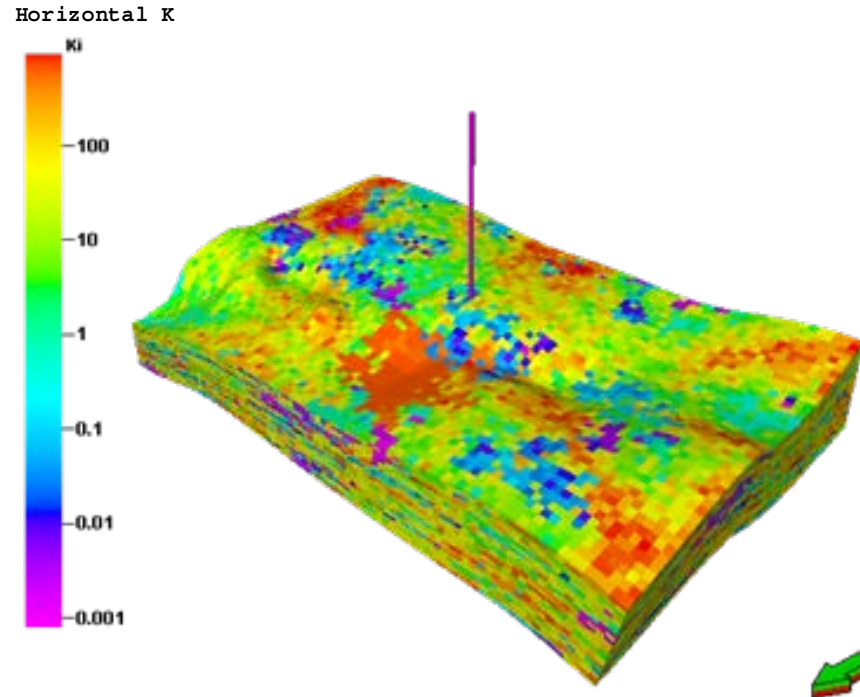
Instantaneous permeability profile of a commingled two-layer reservoir. The red curve is the numerical instantaneous permeability profile for the upper layer and the grey curve shows the numerical profile of the lower layer (ramp effect). The overall numerical profile (blue curve) is expressed as the power average of two layer profile and fits the analytical instantaneous permeability profile (black curve).

- Numerical Interpretation of Ramp

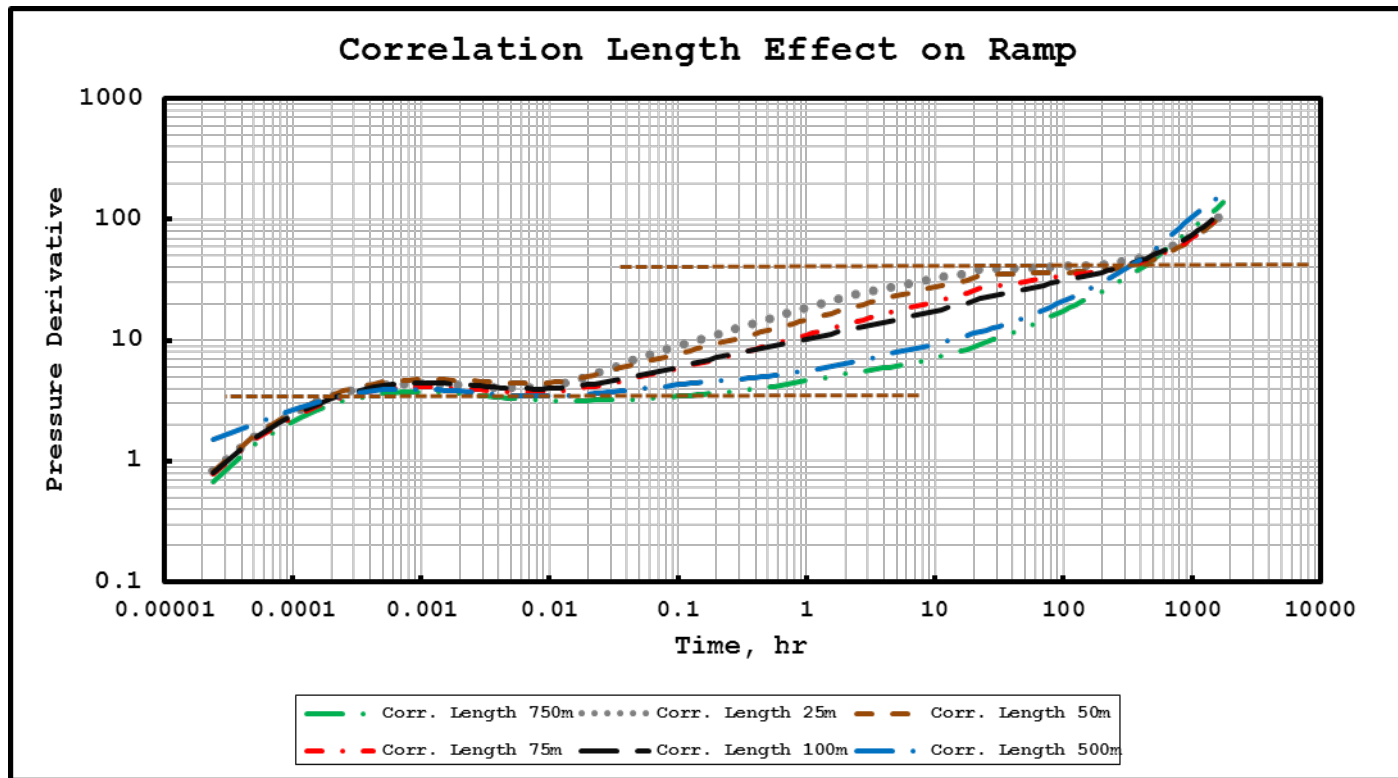
Ramp effect



A heterogeneous model with ramp effect

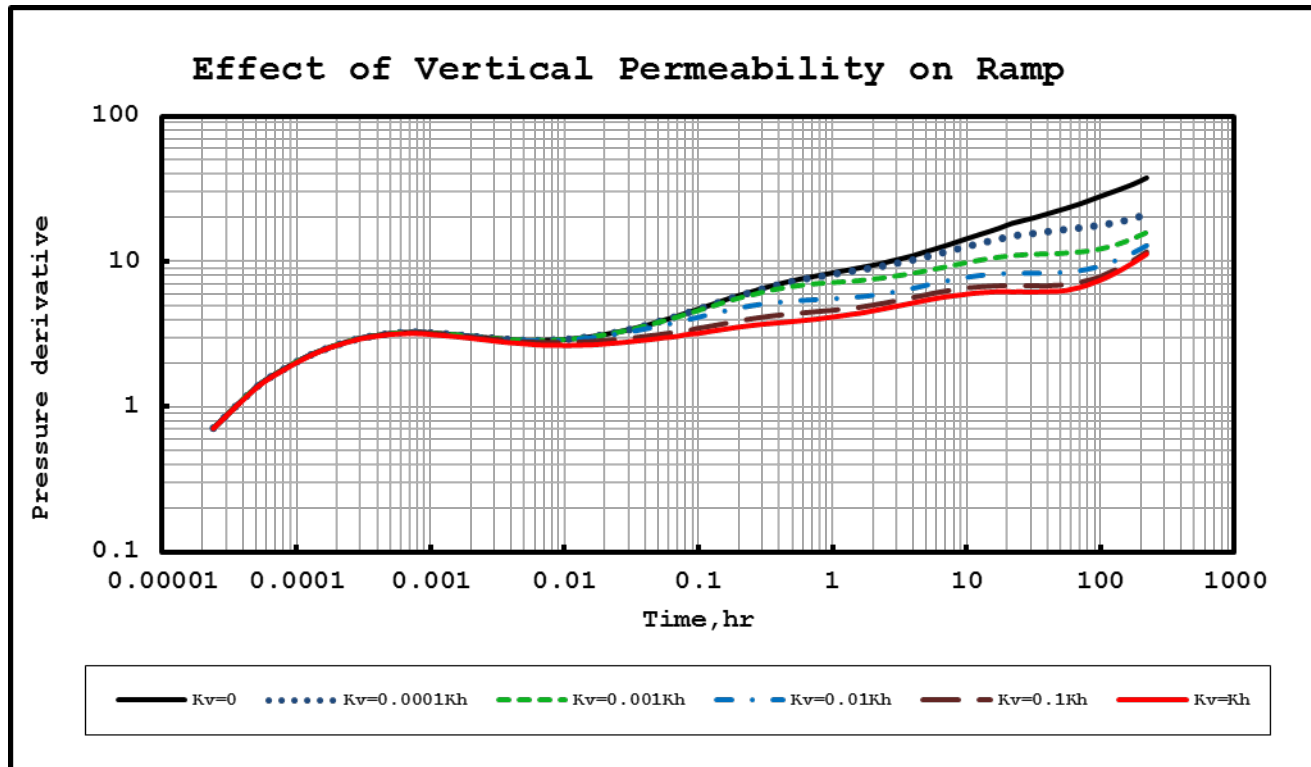


Correlation length effect on ramp

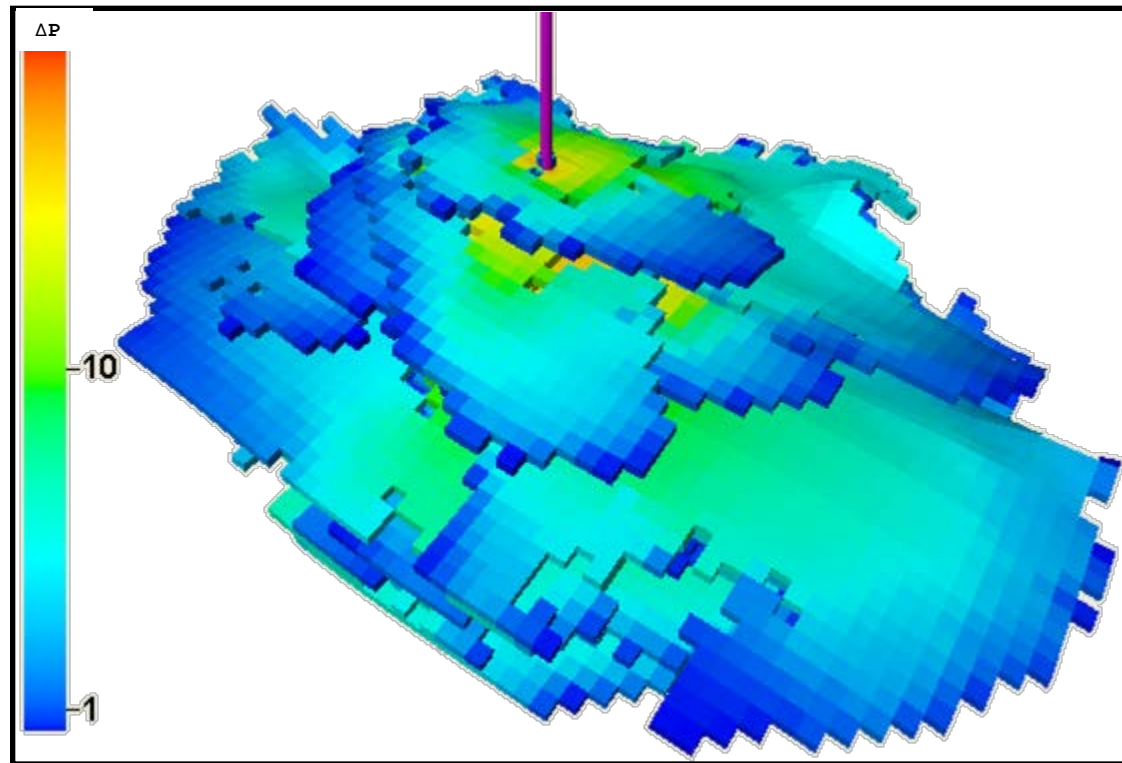


Effect of correlation length on the ramp effect. The longer the correlation length, the longer the initial stabilization, and the shorter the final stabilization

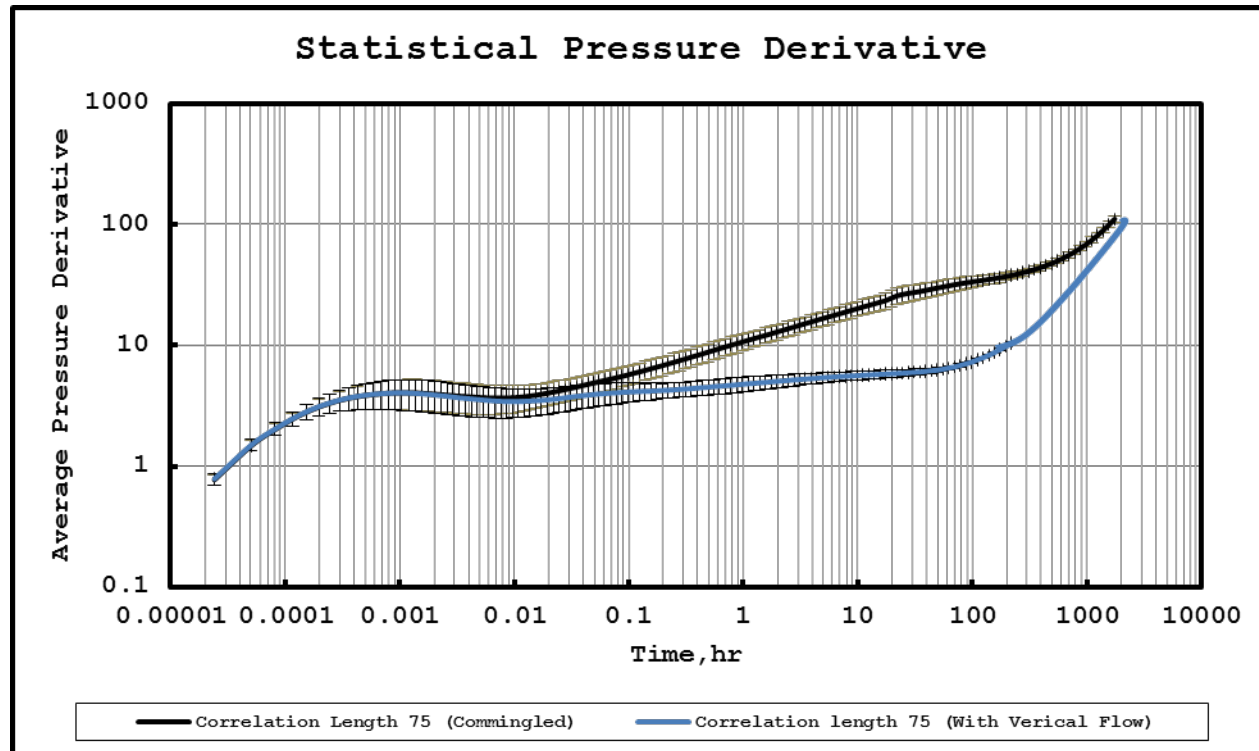
Vertical permeability effect on ramp



Pressure distribution in a heterogeneous commingled reservoir

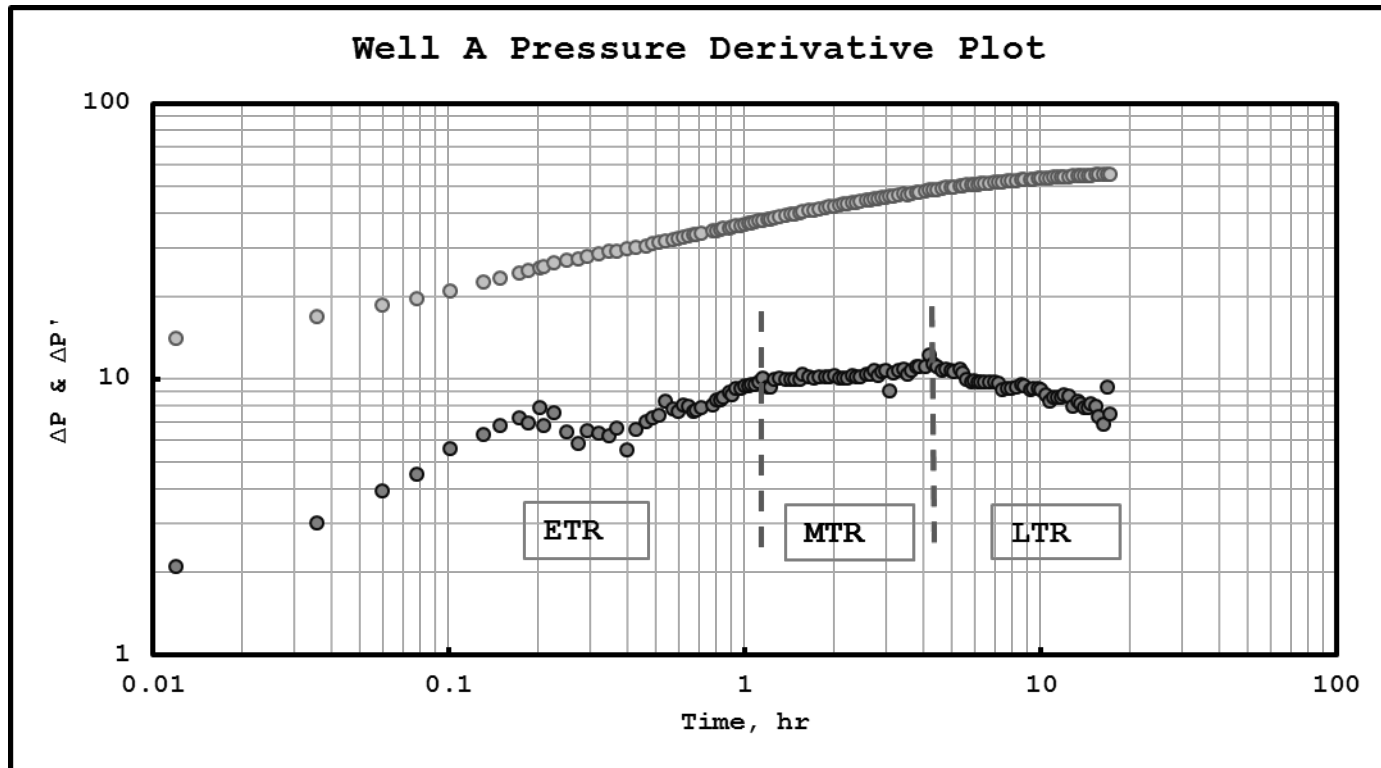


Statistical well test response



- Real case studies

North Sea Triassic Reservoir Geoskin (Ramp) and Geochoke



ETR – Early Time Region – Ramp/Negative Skin

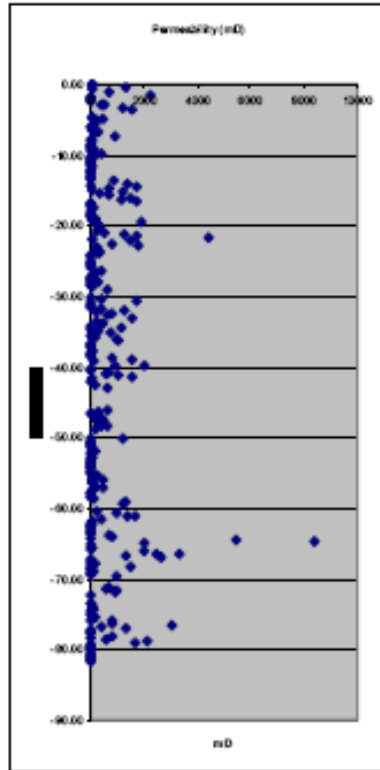
MTR – Middle Time Region – Radial Flow

LTR – Late Time Region – Expanding Flow

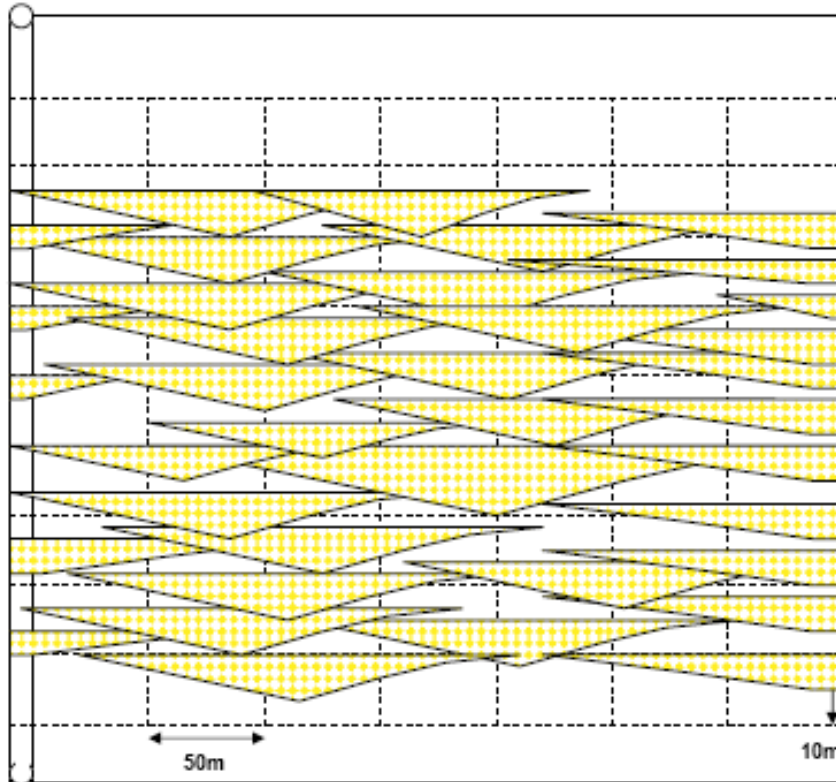
ETR – MTR – LTR >>> Geochoke

Geological Solution

WELL A



Solution



Count	278
Average	456
Geometric	32
Harmonic	0.2
Cv	1.9

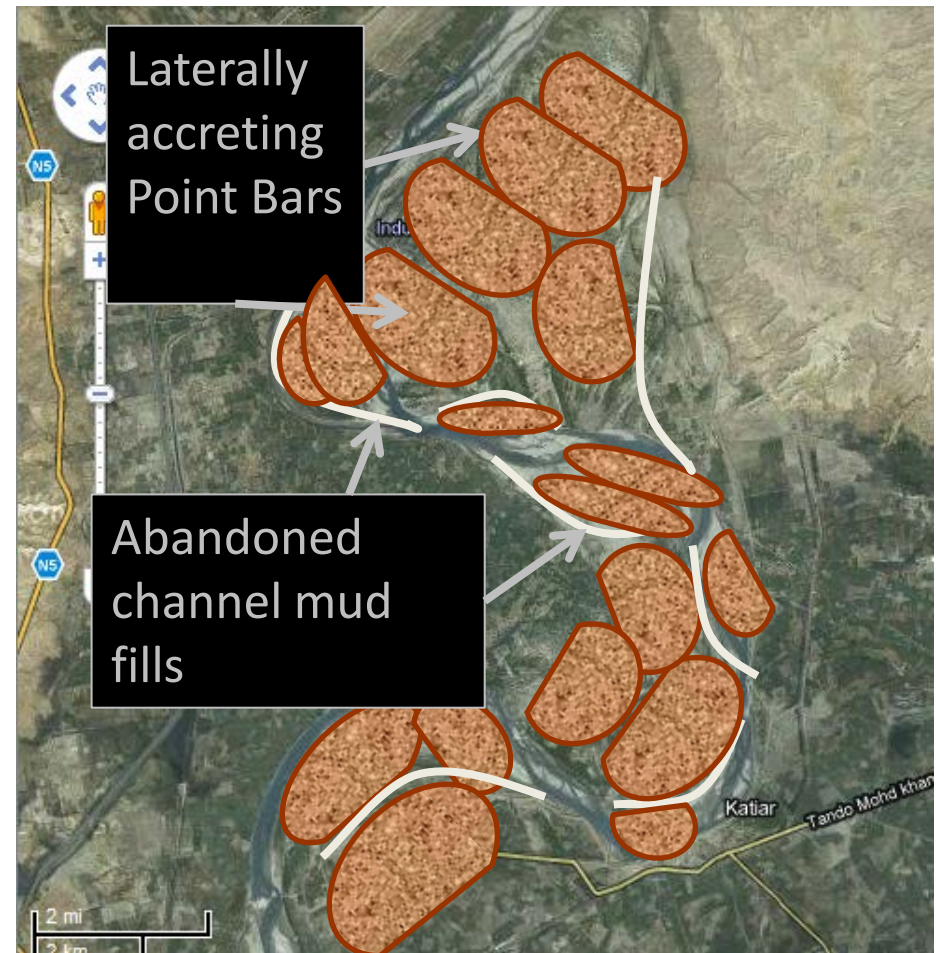
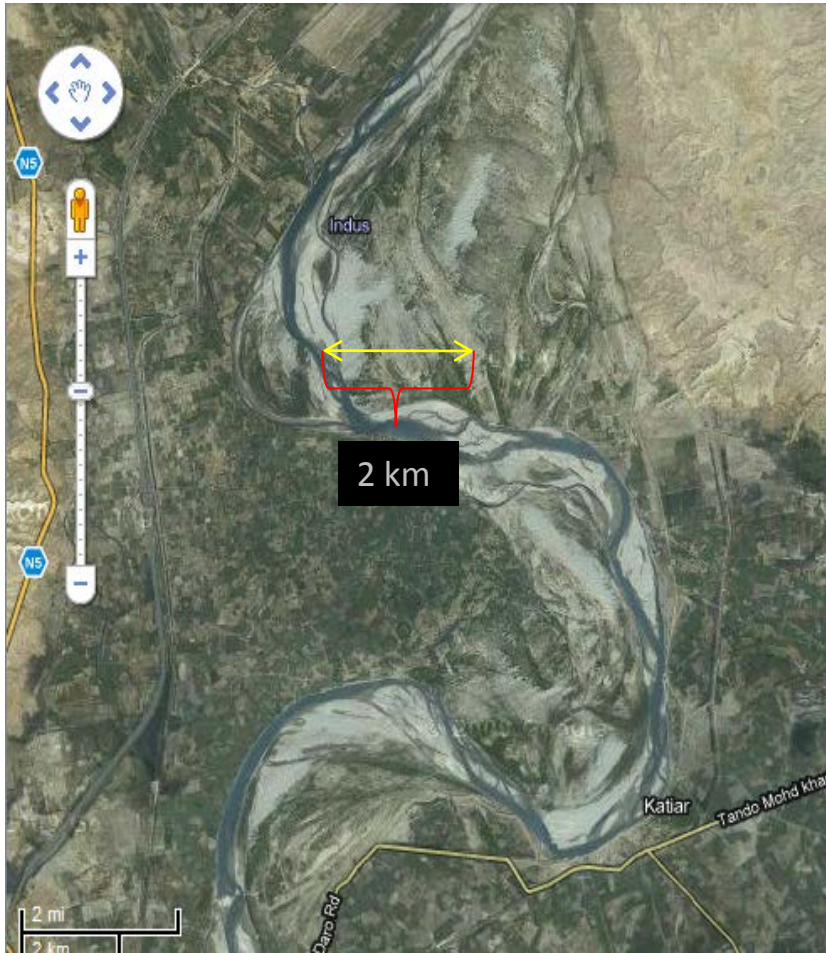
High Net:Gross

Clue: Aspect ratio of about 1:30

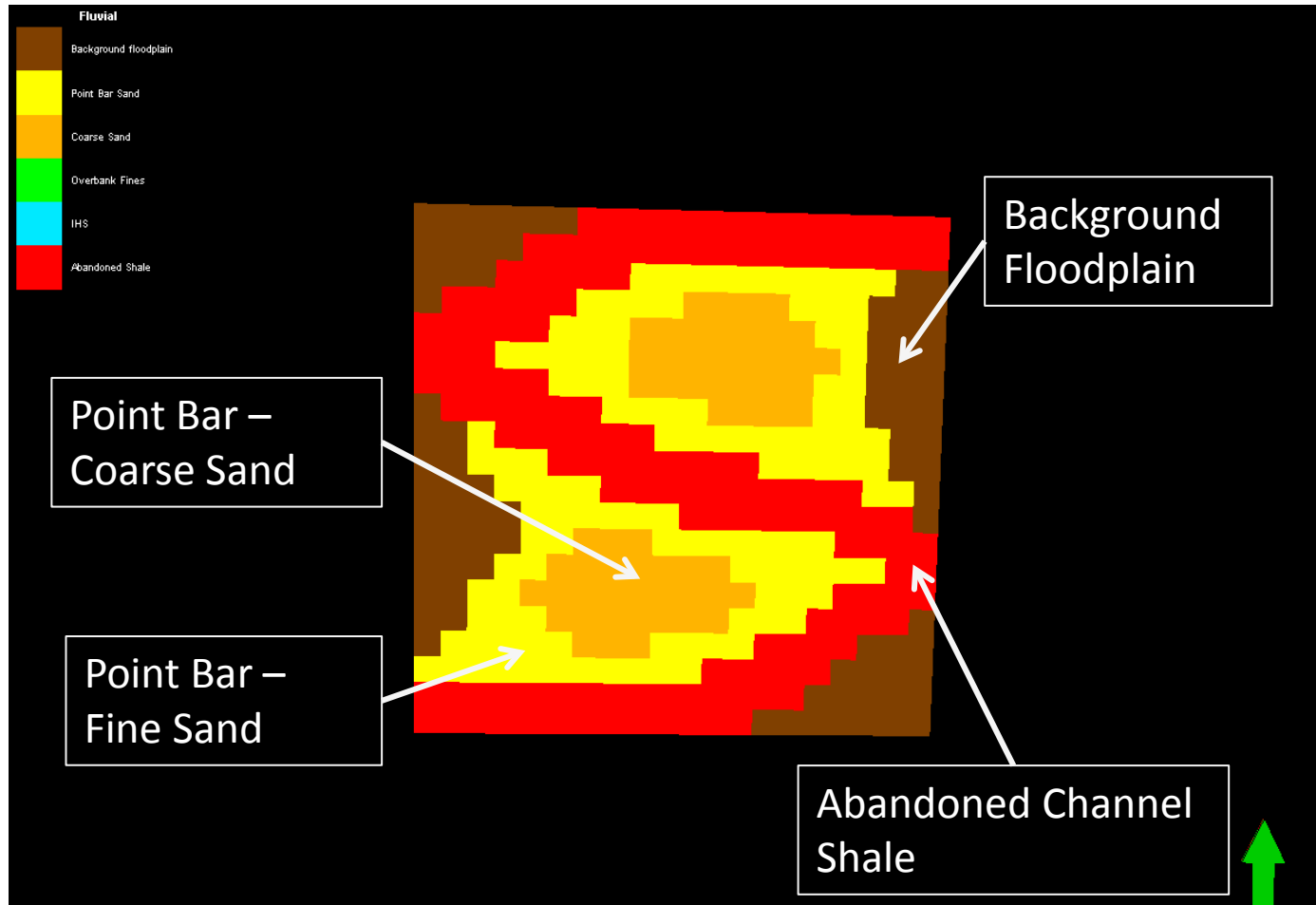
Random System: k_{eff} = Geometric average 32mD

Modern River Analogue

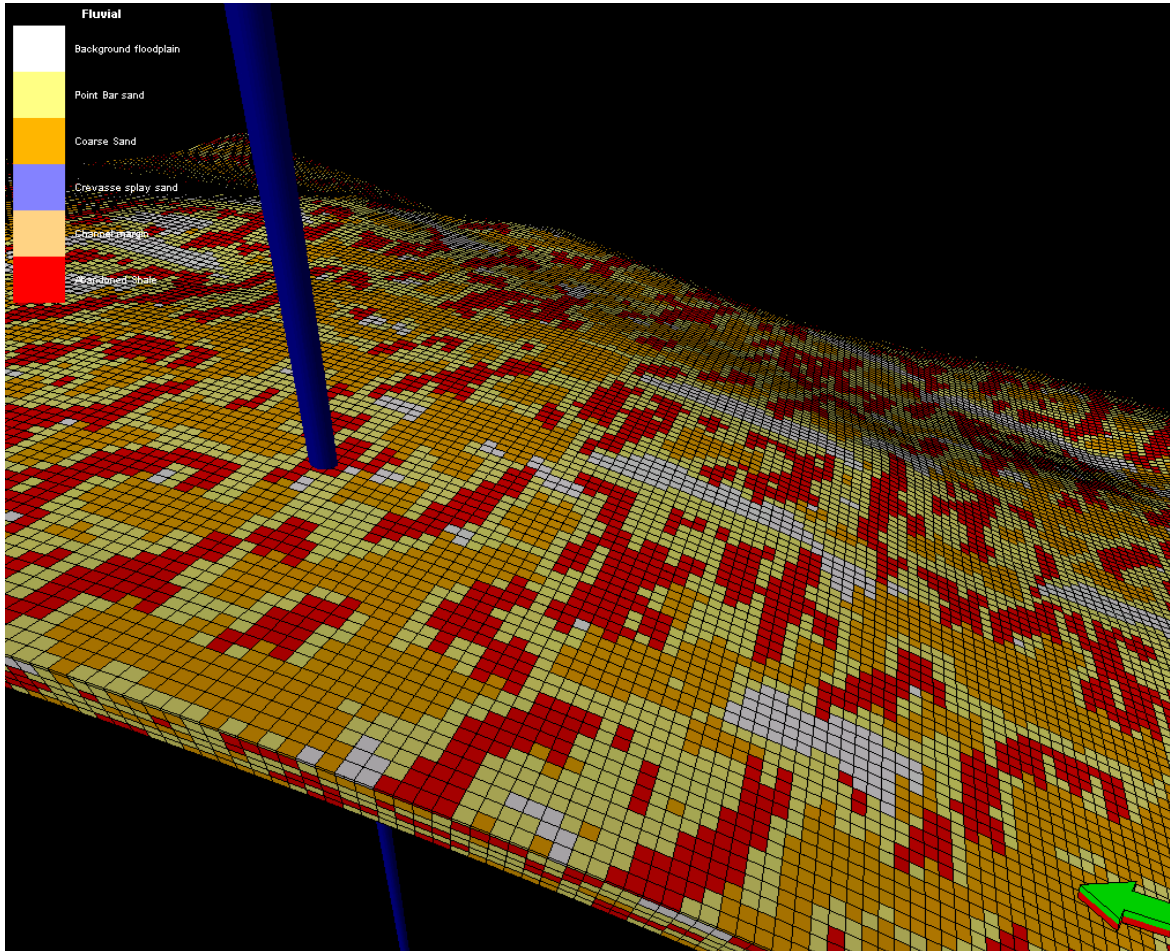
River Indus



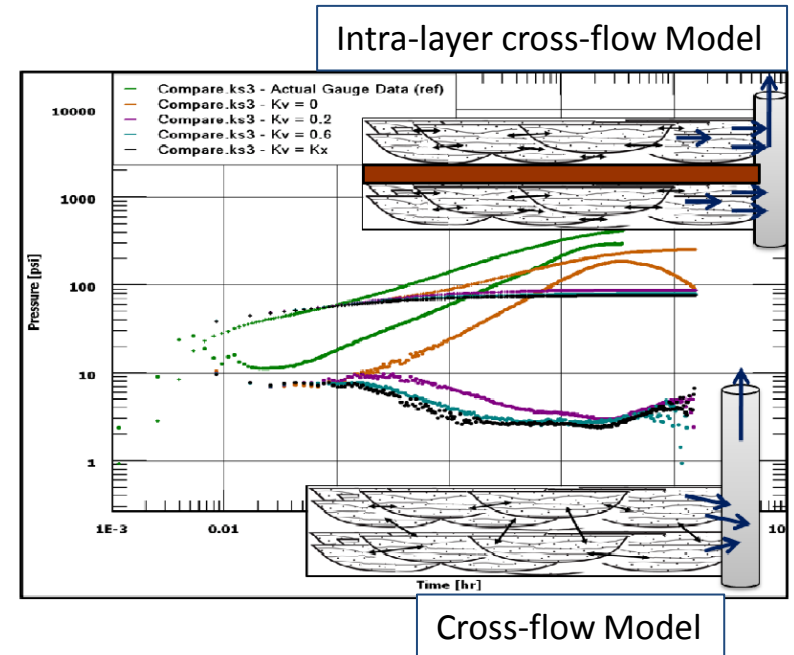
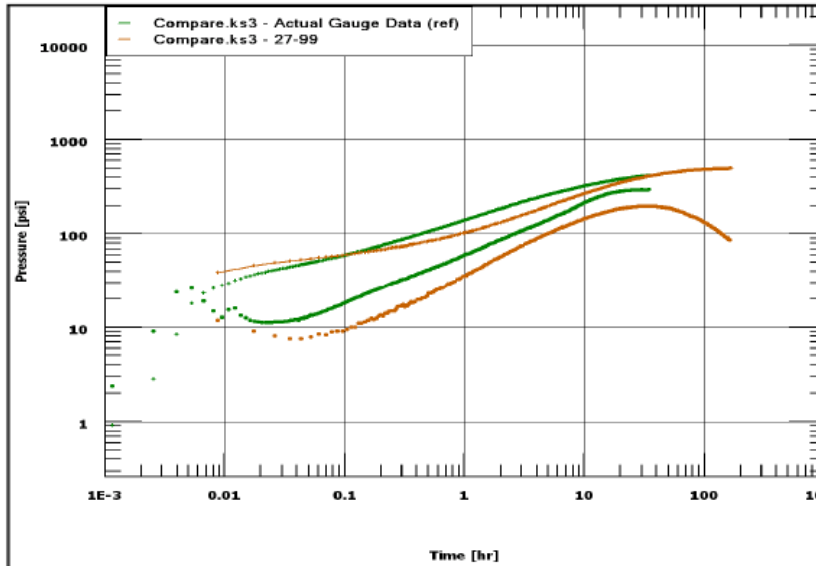
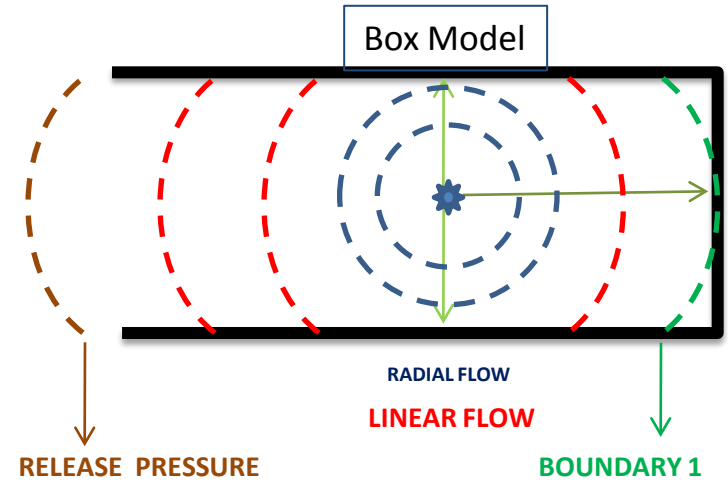
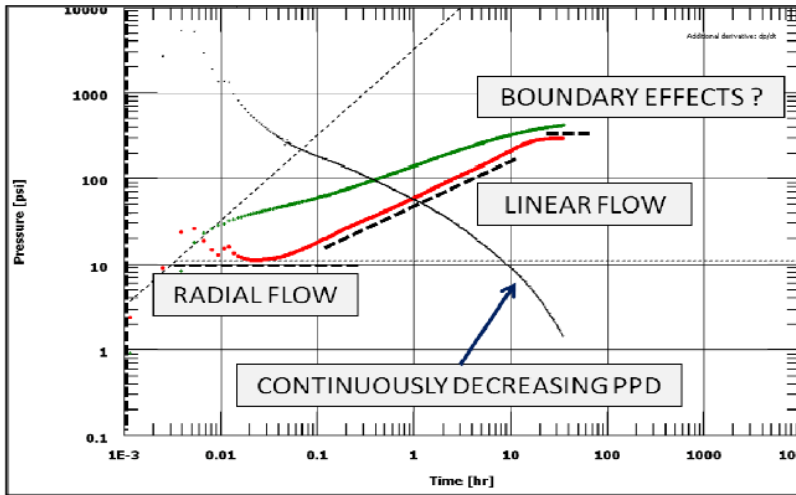
Training Image



Multipoint Facies Simulation

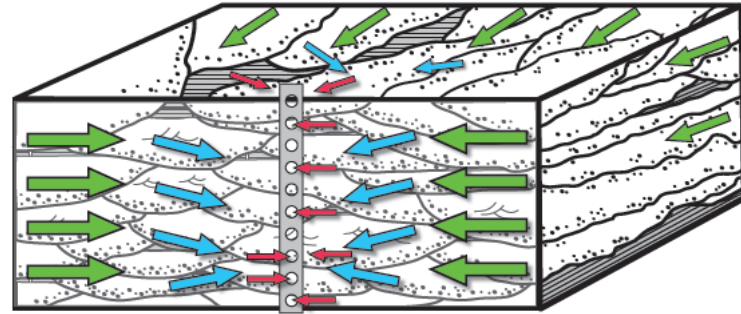
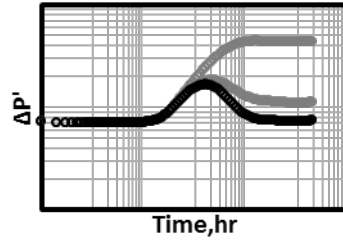


Ramp Effect: Analytical Well Test vs Geoengineering Well Test

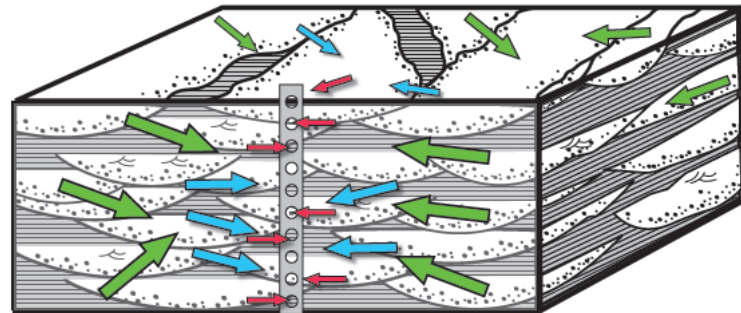
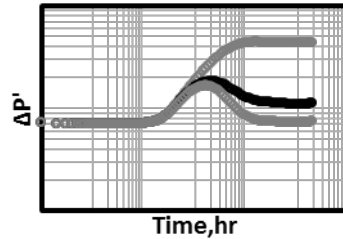


Summary of layered reservoirs with internal crossflow

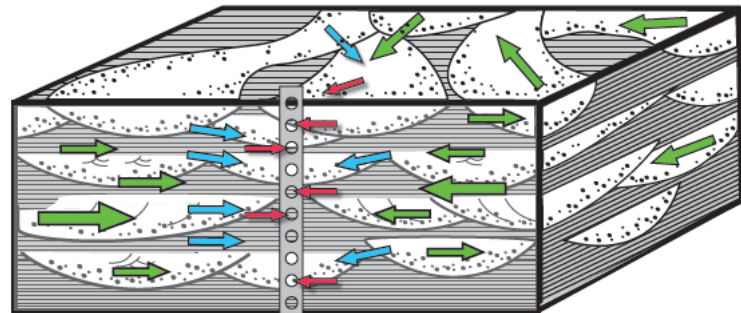
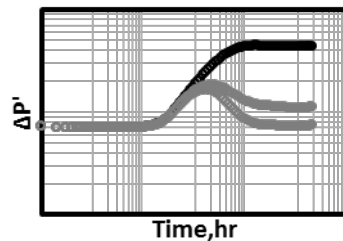
Geochoke



Geochoke - Ramp



Ramp



Conclusions

- **The well-testing family that includes the Geoskin, Geochoke and a new generalised Ramp Effect model is presented for the first time.**
- **Laterally connectivity of facies and the impact of vertical permeability (i.e., vertical connectivity) are critical considerations.**
- **This family of well-testing responses can be described by a series of Geotype Curves which emphasise the ‘continuum’ nature of the responses.**
- **Fluvial systems will be characterised by these responses – where there is good connectivity**

Conclusions

- **Internal crossflow can be confused with external layer crossflow and with other linear flow responses (e.g., parallel faults, natural or artificial fractures).**
- **The ramp effect is part of a suite of well test responses was diagnosed and characterized.**
- **Different numerical, analytical and statistical approaches were used in study of the ramp effect**
- **The vertical permeability is a key in the evolution of the ramp effect : the higher the vertical communication, the lower the ramp slope**

Conclusions

- **The ramp effect is a function of the correlation length : The longer the correlation length the longer the initial stabilization.**
- **The Ramp Effect has been validated by a Geoengineering approach against a real data set. It increases the uncertainty! That can be reduced by other data(seismic)**

Acknowledgement

- Cairn India and Amit Pal Singh
- Total E&P UK Ltd
- Schlumberger (FloGrid, E100, FloViz, Petrel)
- Kappa (Saphir)
- Weatherford(Pansystem)

References

- Ramon W. Alvarado, Lagoven S.A. 1994 :“The Role of Pressure Transient Analysis in Reservoir Characterization: An Integrated Approach”, SPE 23687
- Dahroug, A., Zheng S-Y. & Baily, J. 2005 :“The application of transient pressure testing to track phase boundaries during production - A one well case study from UKSC”, SPE 94446.
- Corbett, P. W. M., Ellabad, Y., Egert., K., & Zheng, S-Y. 2005: “The geochoke test response in a catalogue of systematic geotype well-test responses”, SPE 93992, presented at SPE
- Massonnat, G.J., Norris, R.J., Chalmette, J-C., 1993: “Well Test Interpretation in Geologically Complex Channelized Reservoirs”,SPE 26464
- Herweijer, J. C. & Dubrule, O. 1995:“ Screening of geostatistical reservoir models with pressure transients”, *Journal of Petroleum Technology*. 47 (11), 973-979, SPE 28434
- Oliver, D. S. 1990: The averaging process in permeability estimation from well-test data. SPE 19845, *SPE Formation Evaluation*, 5(3), 319-324.
- Corbett, P. W. M., Mesmari, A. & Stewart, G. 1996: “A method for using the naturally-occurring negative geoskin in the description of fluvial reservoirs”, SPE 36882, European Petroleum Conference , Milan, 22-24 October .
- Gourav, H., 2010, Validating well test response in fluvial systems using multipoint statistics, Unpublished MSc Thesis, Heriot-Watt University.