# MAXIMIZING PRODUCTION: CBM WELL TESTING AND DATA MANAGEMENT

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(PERTAMINA CBM FIELD VISIT & WORKSHOP)

18-22 JUNE 2013

QLD, AU

DECISIONS WITH CONFIDENCE

RISC

# RISC ADVISORY

RISC (Resource Investment Strategy Consultants) is an independent advisory firm. We work in partnership with companies to support their interests in the oil and gas industry, offering the highest level technical, commercial and strategic advice to clients around the world.

With our input, clients are able to make key decisions with confidence. RISC delivers opinions, information and advice that considers the entire picture.

RISC offers a totally independent and broad perspective on energy projects, based on years of experience and an in-depth understanding of the industry.


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of oil and gas field value and development potential.

**Peer Assistance**

to clients including value optimisation and risk mitigation strategies.

**Advisory**

Working with clients to identify, develop and execute oil and gas strategies.

**Disclosure**

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# SELECT UNCONVENTIONAL GAS PROJECTS

**RISC CSG EXPERIENCE**

- RISC has been retained to assist with development of an evaluation program and resource assessment for four CSG blocks in Mongolia;
- Independent assessment of CSG-LNG project upstream field development plan on behalf of operator;
- Facilitation of a CSG reserves project financing workshop for a world scale CSG-LNG project, Queensland, Australia;
- Technical and commercial due diligence evaluation of the APLNG project for Sinopec. Sinopec acquired a 15% stake in the APLNG project for $1.5 billion and a 20 year 4.3 Mtpa offtake agreement;
- Providing technical and commercial due diligence and reserves report to CNOOC Gas and Power on the acquisition of interests in the QCLNG Project. The RISC report has assisted CNOOC in seeking and attaining government project approval and has led to a LNG sales Contract with BG Group for LNG manufactured at QCLNG over a 20 year period, valued at A$50 billion (ABC News) and an equity interest in the project of US$270m (JS Herold);
- Participation in upstream project gate review for CSG-LNG project, Queensland, Australia;
- Lead adviser providing technical and commercial due diligence, financial modelling and reserves certification for acquisition of interest diligence for two major CSG to LNG projects in Australia and one with CSG to LNG potential;
- Resource assessment, conceptual development planning and introductory training for CBM project, Mozambique;
- Resource assessment, pilot test evaluation and development plan optimization for CBM project, West Bengal;
- Evaluation of resource aggregation options for CSG-LNG company in Queensland, Australia;
- Review of the exploration potential for conventional and CSG in the Galilee Basin, Queensland;
- Technical and commercial due diligence for Kogas acquisition of 10% of Blue Energy and permit farm-in options;
- Financial modelling of domestic CSG contracts and options;
- Evaluation of a pilot project performance and commercialisation potential in the Galilee Basin, Queensland, Australia;
- Independent Audit of reserves for a 250 PJ gas project in support of a gas sales agreement, Walloon coal Measures, Queensland, Australia;
- Independent Audit of reserves for a CSG to LNG project, Queensland, Australia;
- Independent assessment of in-place and recoverable CSG to support an acquisition in Indonesia;
- Independent Expert's Report for IPO on Indonesian CSG play;
- Independent Technical Specialists report for Comet Ridge's proposed merger with Chartwell;
- Independent report on CSG Resources for South Wales CSG Project, UK;
- Independent report of resources for portfolio of European CSG properties;
- Technical and commercial due diligence support for the acquisition of the Baode CSG project, China in the pilot test phase.
- Reserves and resource evaluation and cash flow analysis for the Shouyang Contract Area, China

# SELECT UNCONVENTIONAL GAS PROJECTS

**RISC Shale Gas Experience**

Examples of recent assignments and team experience include:

- Independent Technical Specialist's Report for Adelphi Energy Limited's US assets in the Eagleford Shale including resource estimate, gas and condensate values, well productivity and decline, development scenarios, production forecasts, development costs
- Review of Australian unconventional gas opportunities for Japanese client
- Technical and commercial review of the potential for shale gas in the Perth Basin Australia identifying the main potential horizons, in-place volumes and economic scenarios
- Review of the potential of the Canning Basin Australia as a new frontier for shale gas including commercial analysis of both domestic and export (LNG) gas markets
- Desk studies including compilation of analogue data from all USA shale gas regions
- Scoping study of Australian shale gas opportunities including analysis of prospective formations in different age basins, gas contents, reservoir type and continuity, identification of prospective zones from wireline and mud logs, resource estimate
- Evaluation of shale gas projects, land leasing, drilling projects in West Virginia and Kentucky including the new Marcellus play
- Management of equity interests in the US Appalachians Devonian shale
- Drilling projects for Devonian Shale in Kentucky

**RISC Tight Gas Experience**

Examples of recent assignments and team experience include:

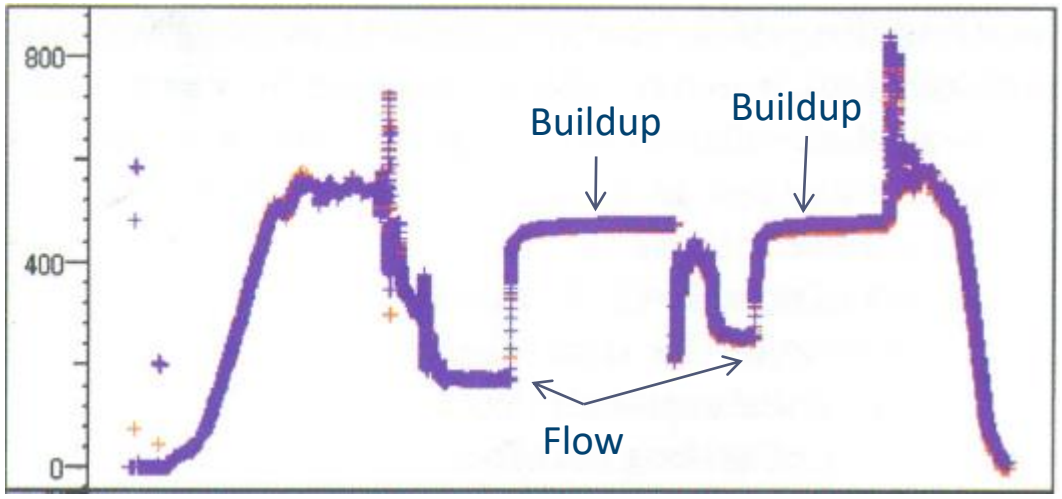
- RISC provided an independent Technical Specialist Report on tight gas assets in the Ordos Basin, onshore China, for Sino Gas & Energy's listing on the Australian Stock Exchange
- RISC conducted an independent review of the reserves, deliverability and further development potential of a tight gas field, onshore Perth Basin
- A number of evaluations of tight gas field development in both the Cooper Basin and Canning Super Basin, onshore Australia

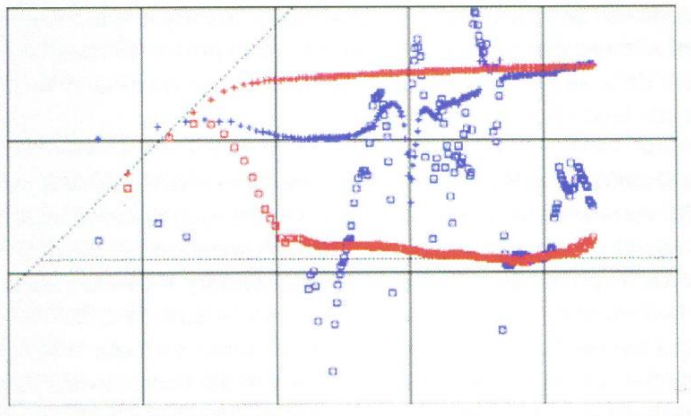
Project management for a tight gas appraisal program including well testing and fracture stimulation, onshore Vietnam

# AGENDA

1. Test types & objectives
   - Old & new paradigms
2. Reservoir management examples
3. Diagnostic fracture injection test (DFIT)
4. Testing in complex situations
5. Test duration
6. Initial and final static gradients
7. Wellbore Dynamics
8. Future of Testing
9. Conclusion

# WHAT IS TESTING TRADITIONALLY?



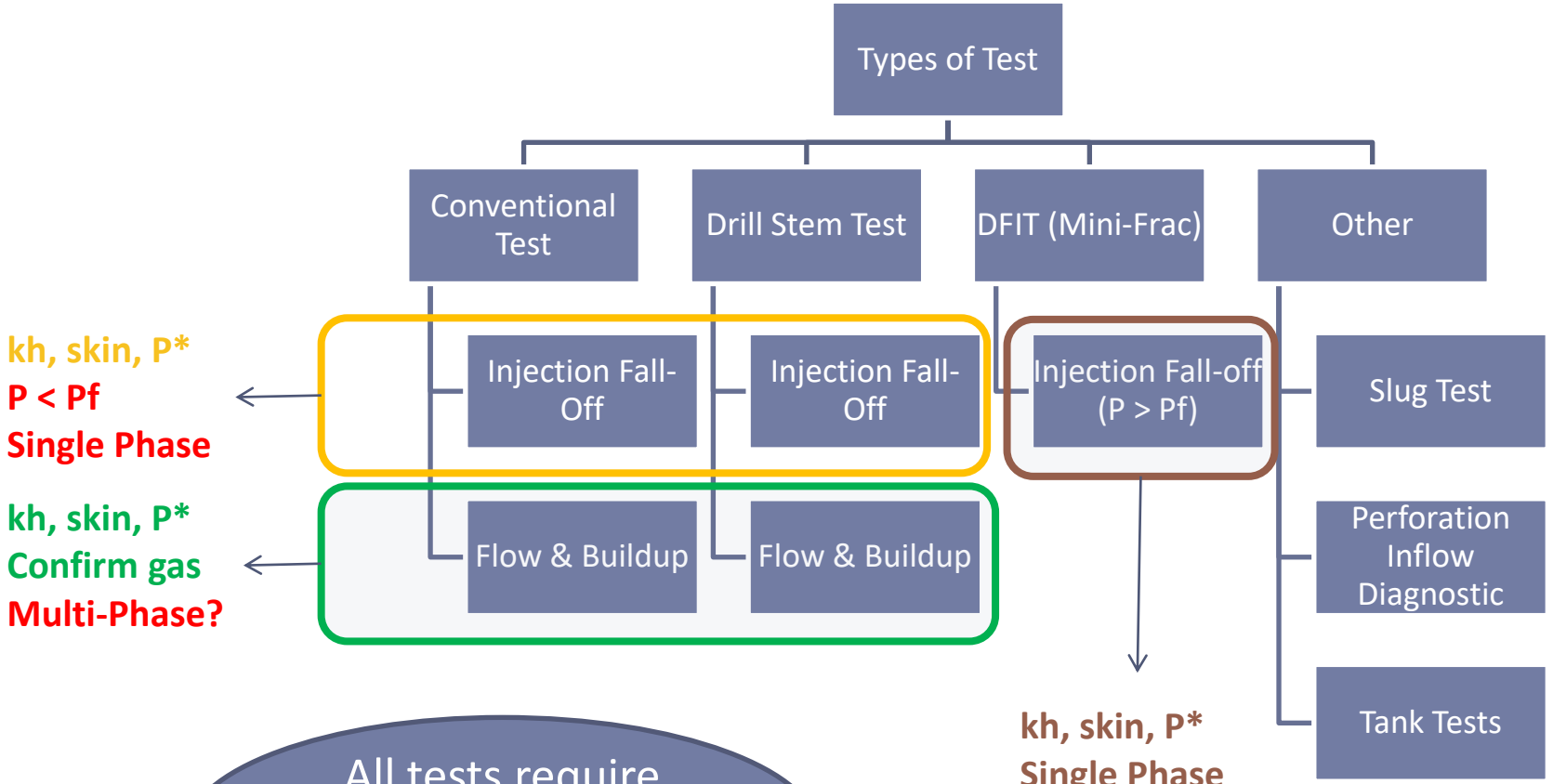
Buildup derivative analysis

A series of fluid is injected or produced from the formation. Analysts evaluate the pressure response for permeability, wellbore skin (Formation damage), and reservoir pressure.

Common tests include DST; Injection Fall-off; Flow & Buildup; Slug Tests; and more

# TYPES OF TESTS

COMMON CLASSIFICATION OF TESTS (OLD PARADIGM)

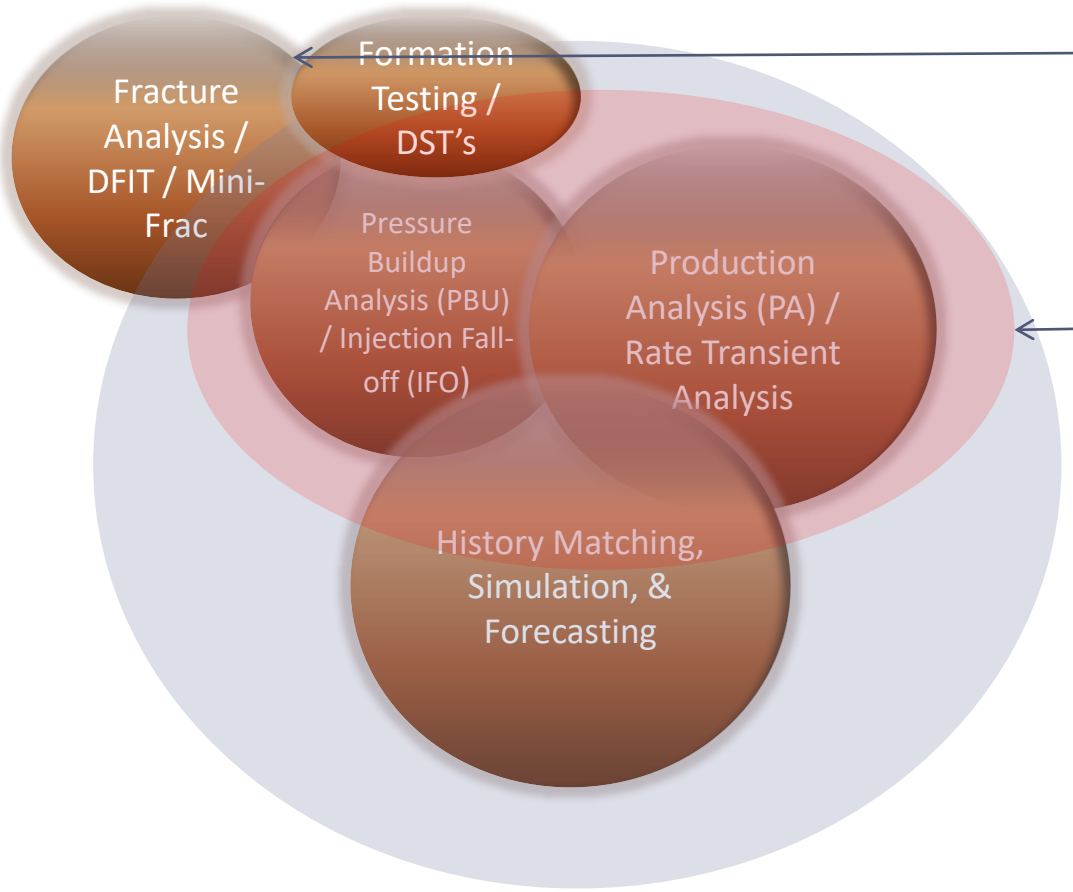



All tests require radial flow for estimate of kh

Not a comprehensive list

# TYPES OF TESTS

NEW PARADIGM OF TESTING & WORKFLOW

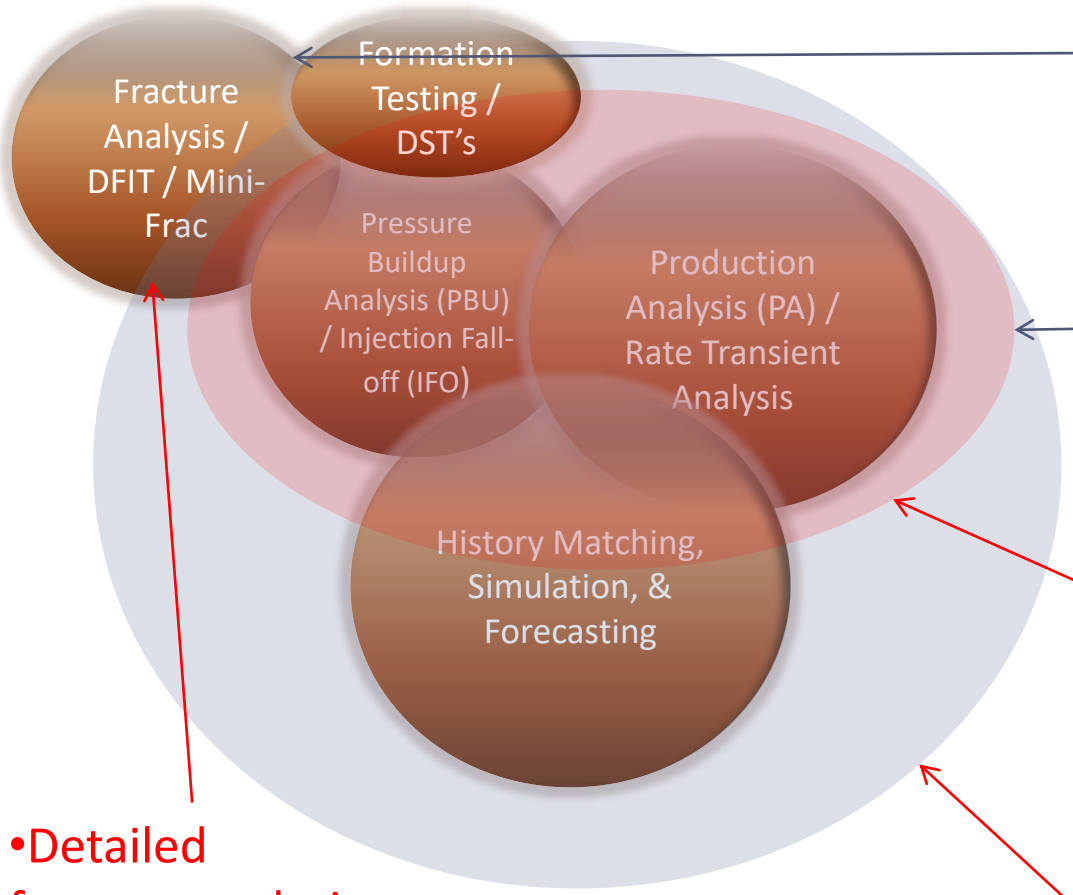



- Emergence of fracture diagnostics linked directly to testing
- Integration of pressure & rate analysis
- Integrated technology platforms (harmony, Ecrin)
- On going data collection

Not a comprehensive list

# TYPES OF TESTS

NEW PARADIGM OF TESTING & WORKFLOW




- Emergence of fracture diagnostics linked directly to testing
- Integration of pressure & rate analysis
- Integrated technology platforms (harmony, Ecrin)
- On going data collection
- Permeability, drainage area, radius of investigation, reservoir pressure
- Long-term deliverability predictions
- Recoverable gas
- Field Development plans
- Detailed fracture analysis

Not a comprehensive list

# TEST OBJECTIVES

- Traditional Short-Term Objectives
  - Permeability
  - Skin (formation damage?)
  - Initial reservoir pressure
  - Boundaries

Generally, IFO, FBU, PDA, DFIT will provide estimates of nearly all parameters.

- New Paradigm Objectives
  - Dewatering Efficiency
  - Reservoir size, and shape
    - Production based analysis
  - Heterogeneity
    - Effective permeability
    - Client orientation
  - Resource and/or reserves

Pressure and rate analysis is progressing from early-time formation evaluation and becoming an integral part of reservoir management.

Modern CSG testing has progressed from DST and IFO to on-going data collection, analyses, modeling, and forecasting.

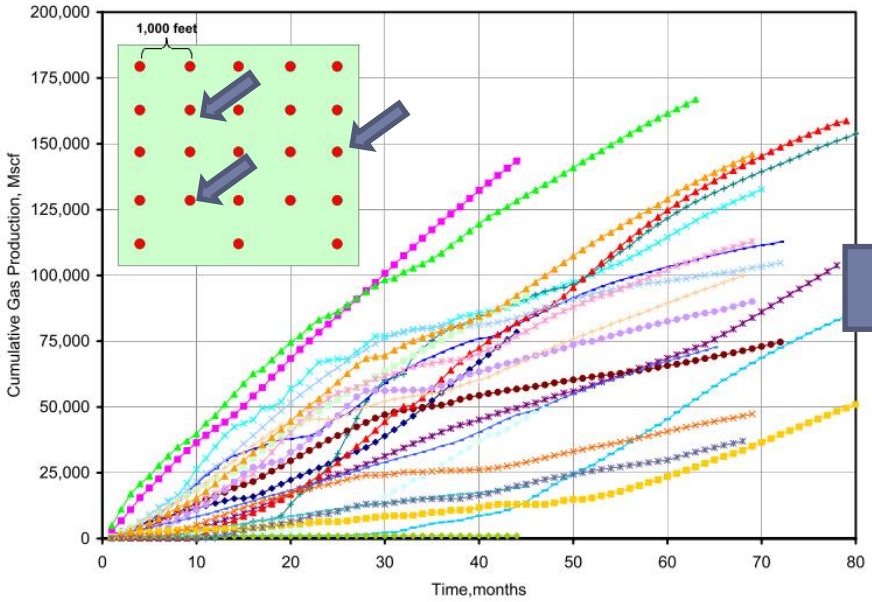
# 2 RESERVOIR MANAGEMENT: ADVICE & OBSERVATIONS

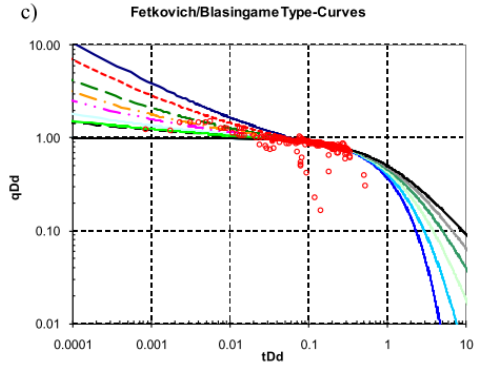
DECISIONS WITH CONFIDENCE

# RESERVOIR MANAGEMENT

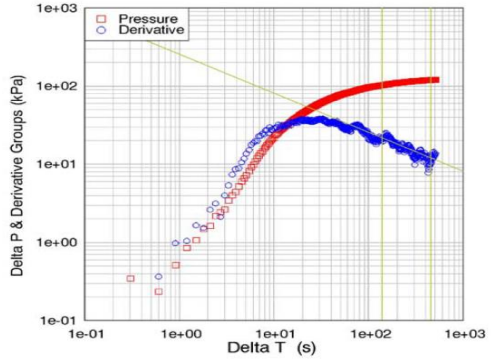
Local well performance variations in a group of 23 wells from the Black Warrior Basin. Differences were attributed to local changes in cleat and natural-fracture permeability

Potential Pressure Test Well Distribution?



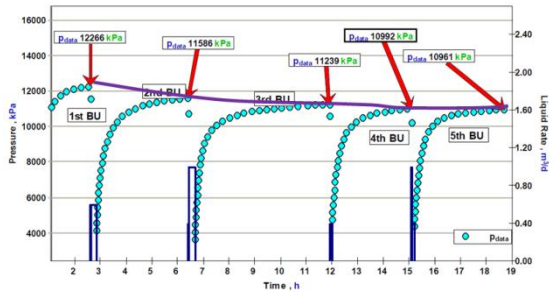




Rate analysis of production periods (Blasingame, NPI, FMB)




Pressure analysis of shut-in data (Traditional derivative analysis)

Development plans should incorporate:
Regular shut-in pressure data;
Both flow & buildups should be analyzed for kh/skin;
Material balance modeling of shut-in pressures

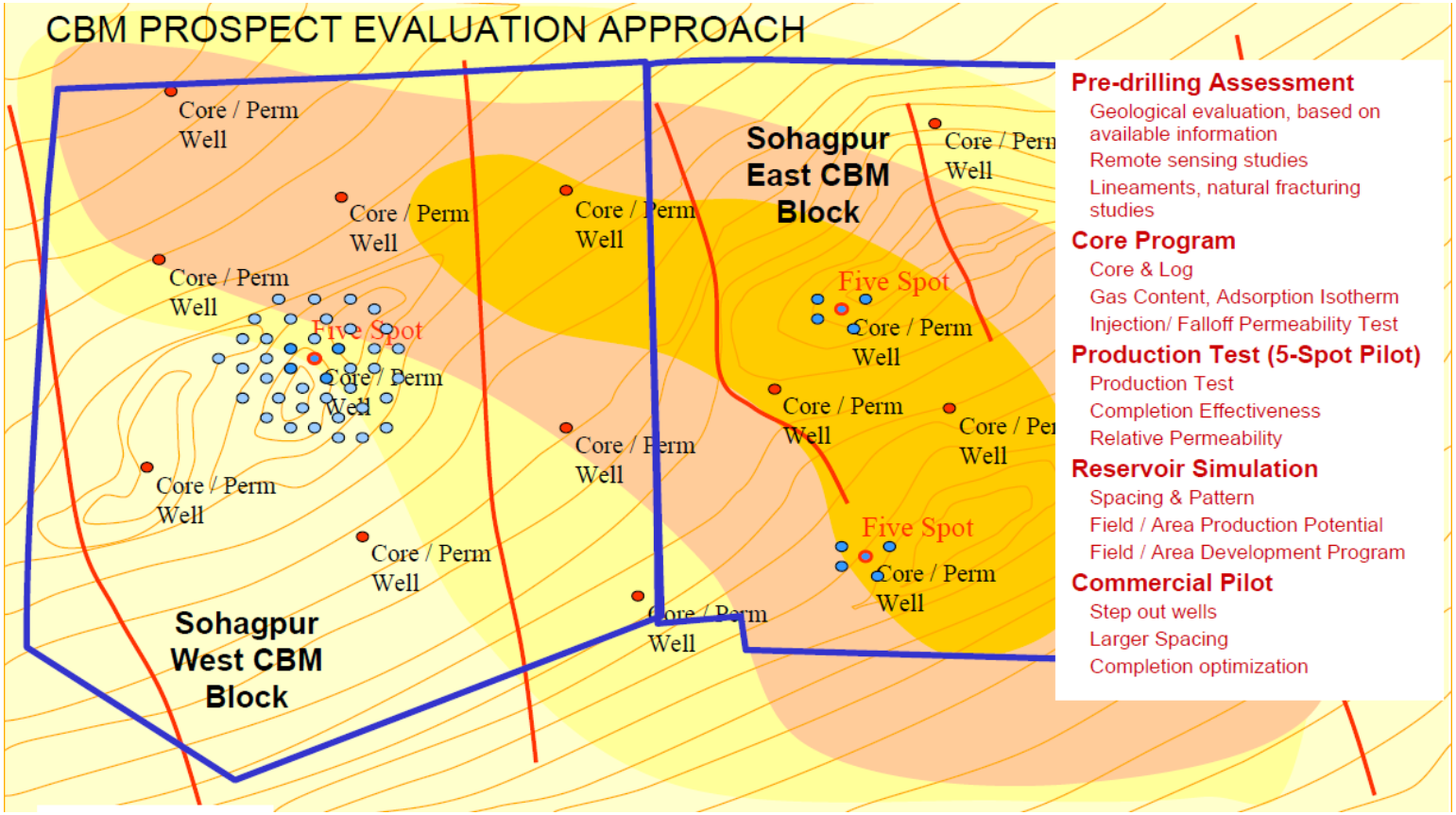



Material balance analysis of shut-in data

Sundaram (2007)

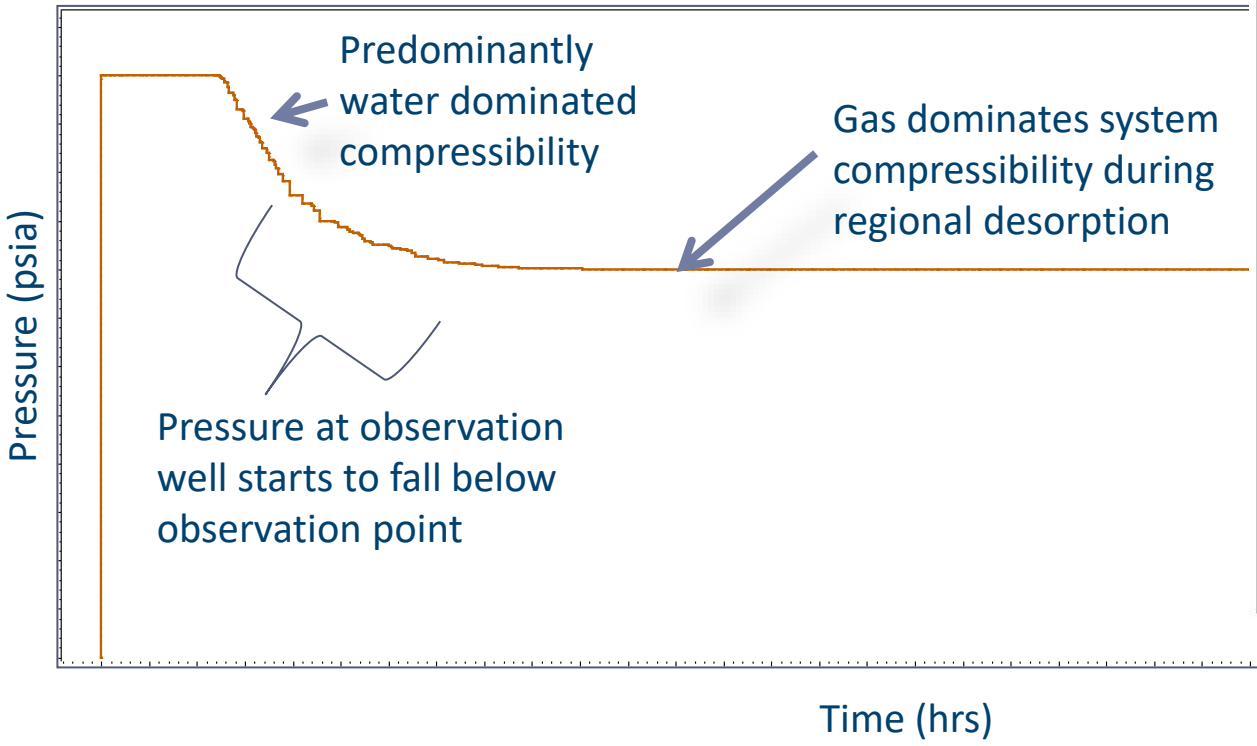
# RESERVOIR MANAGEMENT

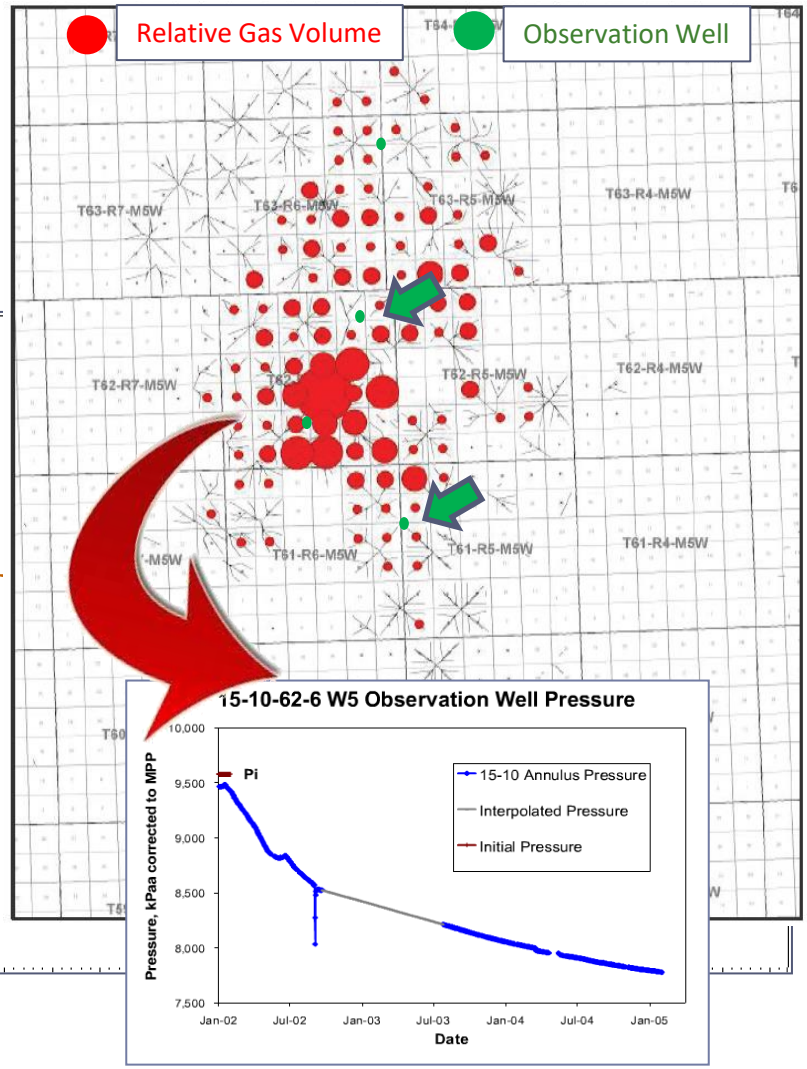
Example demonstrating a range of permeability, core, and production test locations throughout project area. Example drawn from Sohagpur Block in India



# RESERVOIR MANAGEMENT

## Corbett Creek CBM Project(Canada)

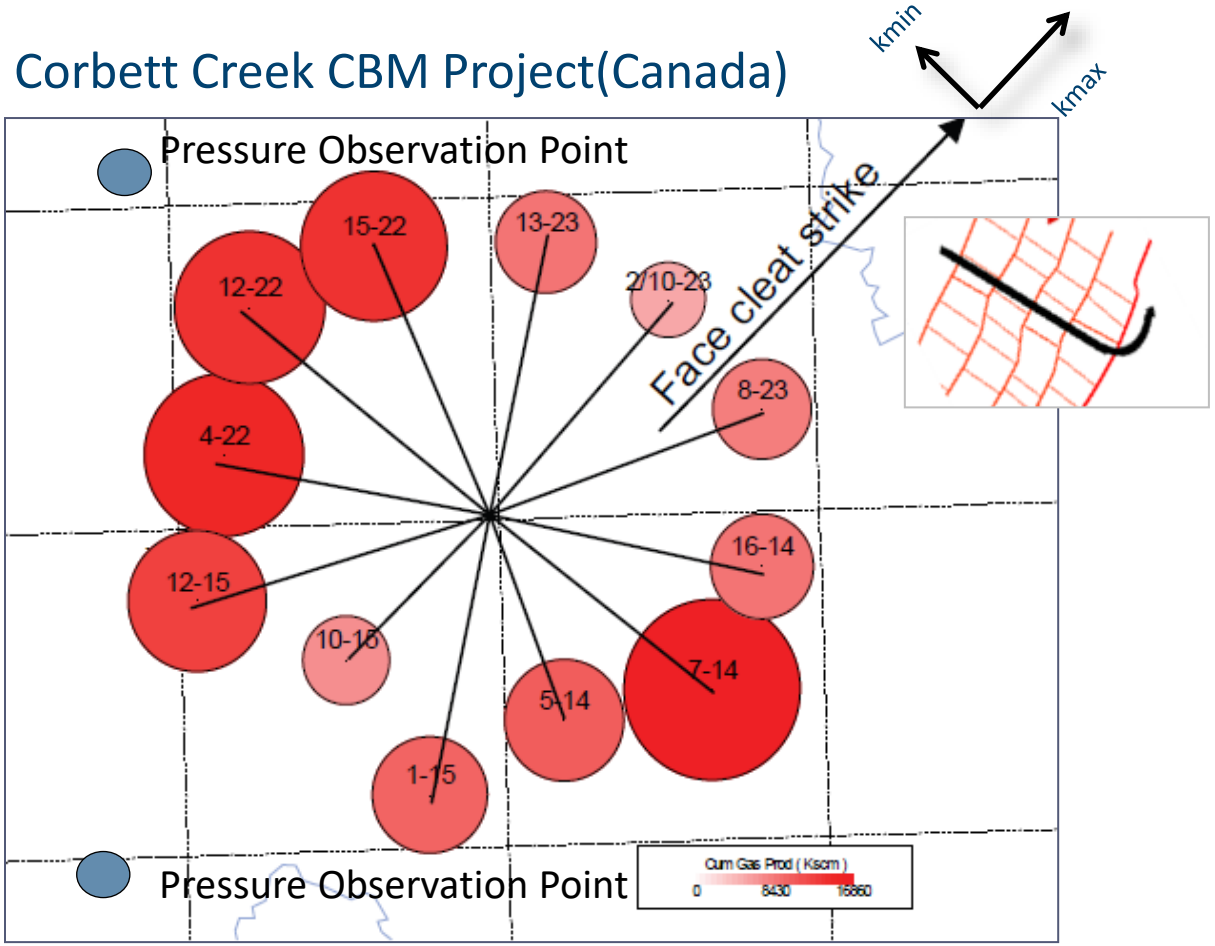



On-going observation wells can be used to help determine if field development area has passed desorption point. Corbett Creek Mannville CBM (Canada) project implemented a series of test wells to observe regional pressure response during development

# RESERVOIR MANAGEMENT

## Corbett Creek CBM Project(Canada)

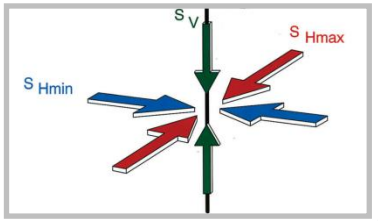



*Numeric values represent well names in Cdn nomenclature*

Pressure and production data was monitored from a series of Hz wells to help characterize cleat orientation

Measured pressure and rate data was supplemented with select pressure observation points

Analysis can be supplemented by core samples and image logs.



# RESERVOIR MANAGEMENT

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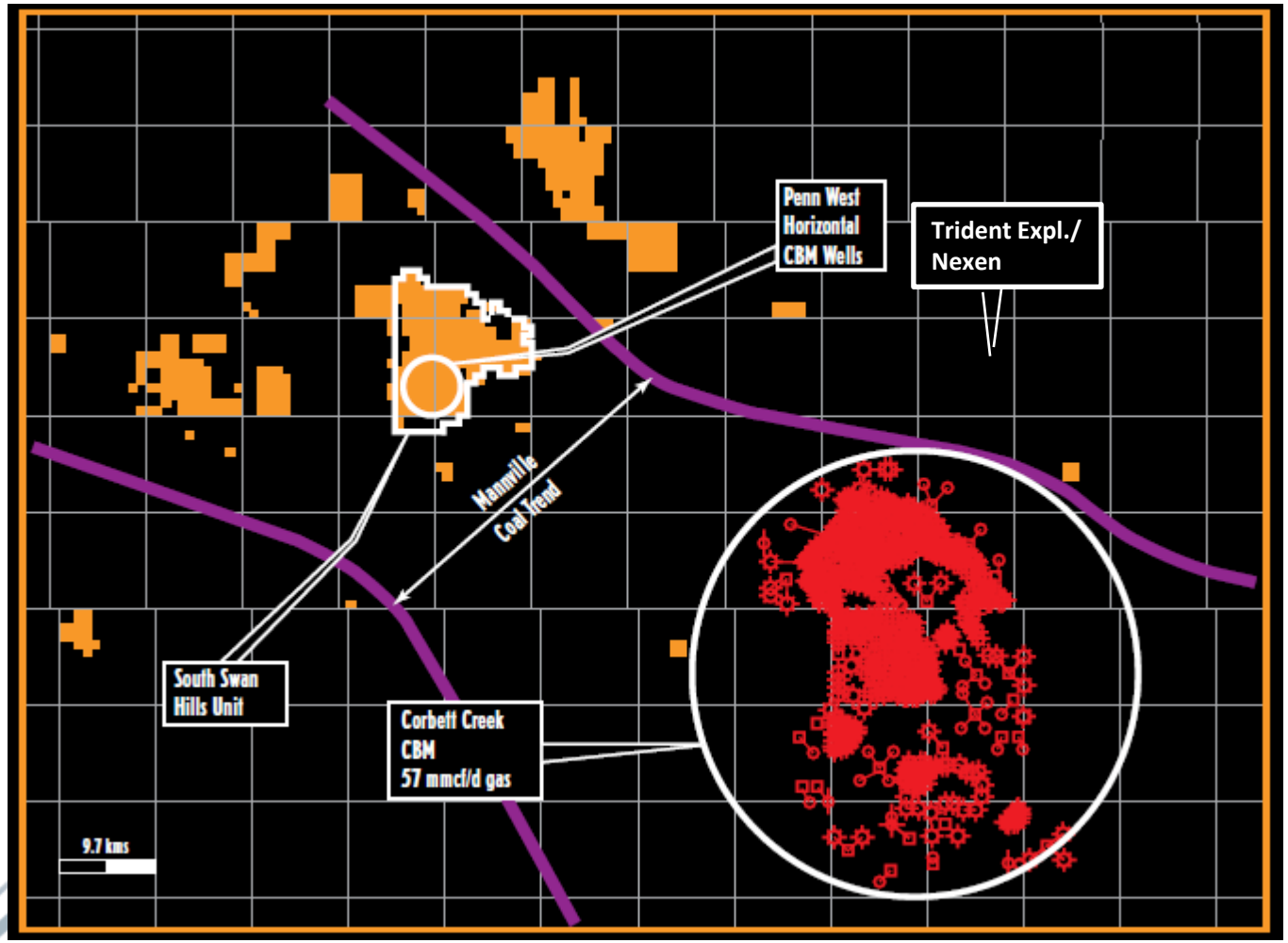


# 4 DIAG. FRACTURE INJECTION TEST (DFIT): ADVICE & OBSERVATIONS

DECISIONS WITH CONFIDENCE

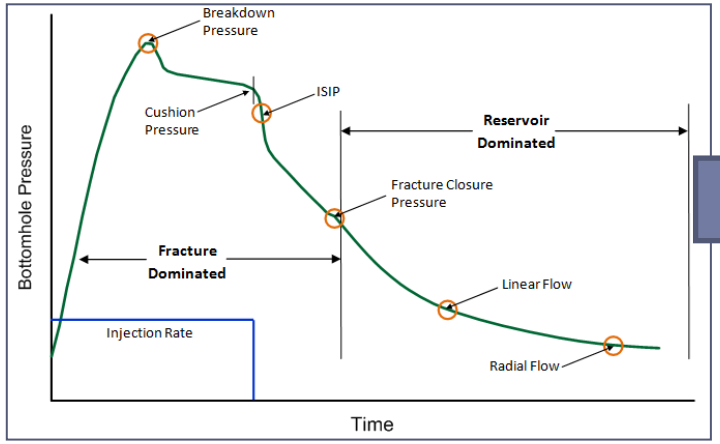
# DFIT / MINI-FRAC

•Simple, cost effective method for estimating pressure and flow capacity (kh), emphasis on formations that require stimulation due to low permeability

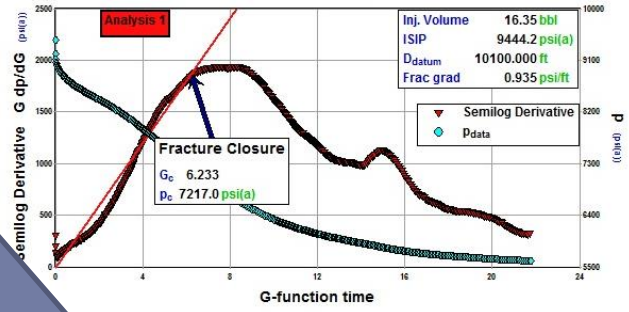
• Also provides information on fracture gradient, fracture closure, and other fracture parameters

• Pressure transient analysis is more complicated

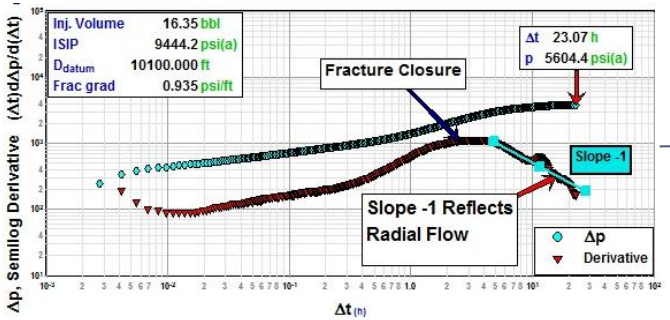
• Interpretation can be challenging (potentially different type curve library)




G-Function Analysis



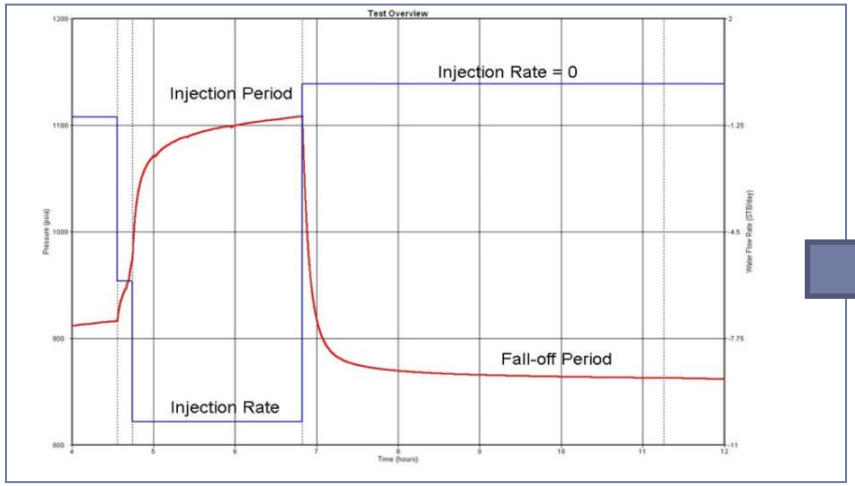

Derivative Analysis

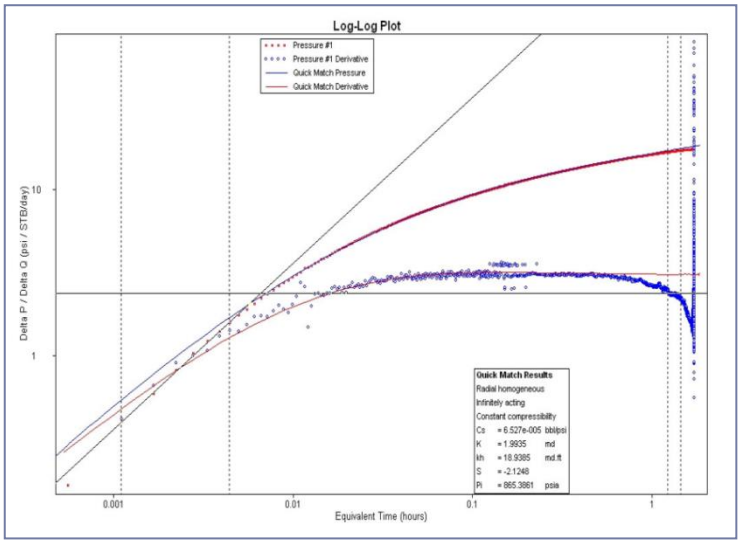



Can evaluate:
kh,
Fracture closure
Leak-off
Fracture growth
and more

# BHP BILLITON ILLAWARRA COALS

If fracture pressure is not reached, a traditional IFO may still exist

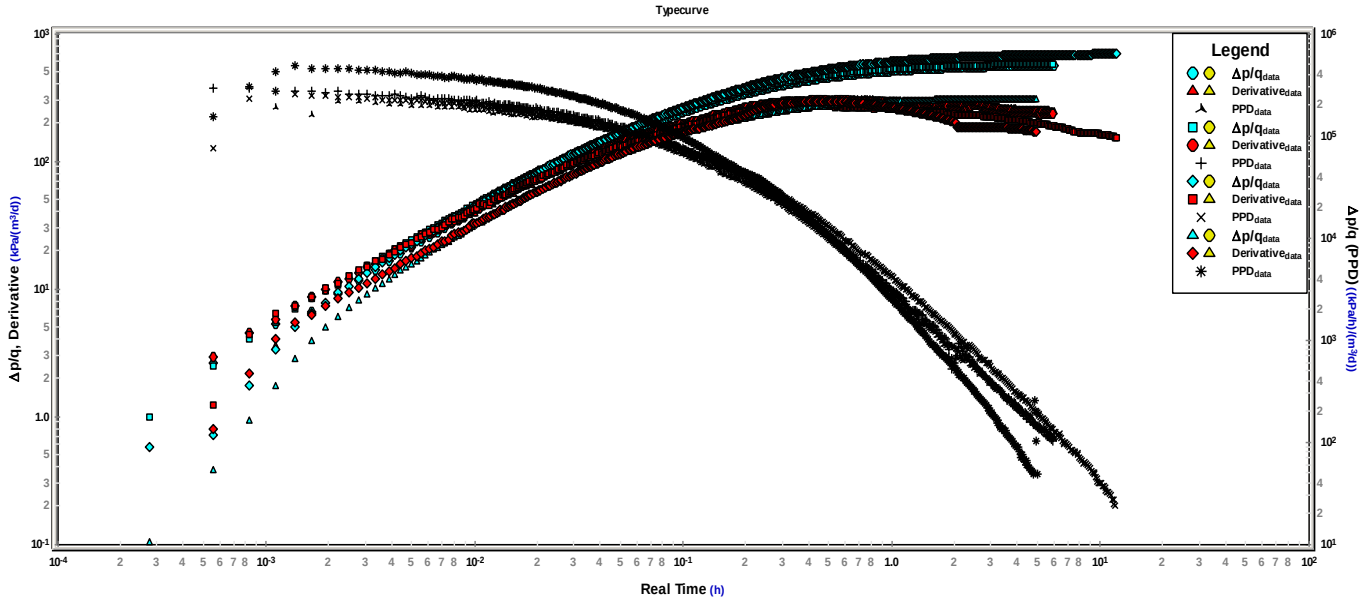


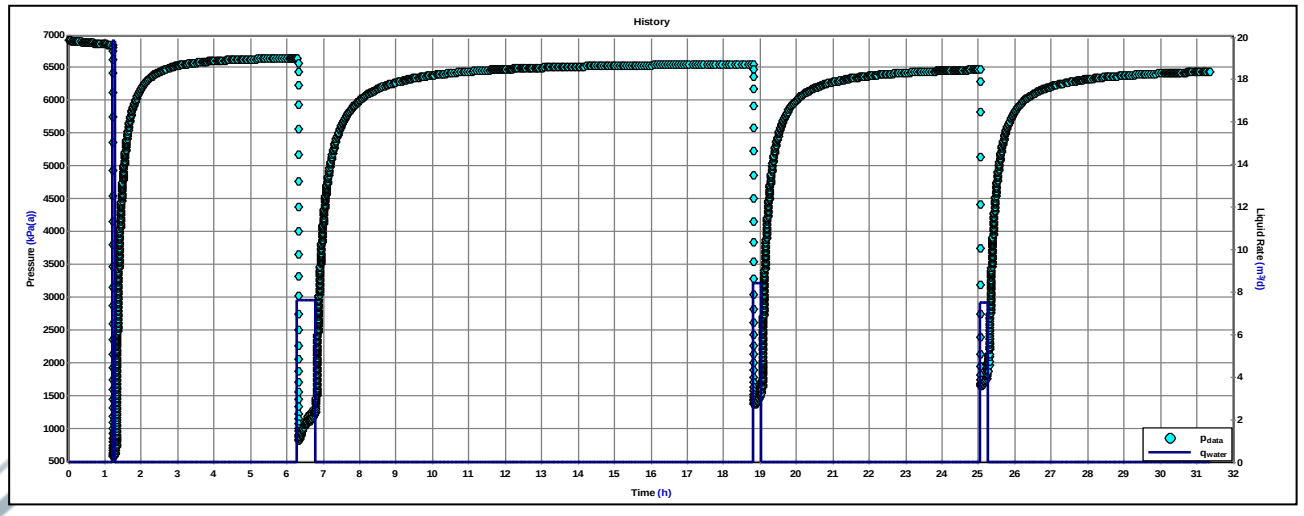



# 4 INTERESTING FIELD EXAMPLES DEMONSTRATING TECHNOLOGY & THEORY

DECISIONS WITH CONFIDENCE

# CHINA CSG DST #1




CSG does not exclusively require DFIT or IFO

Conventional DST with proper test design will provide reliable results.

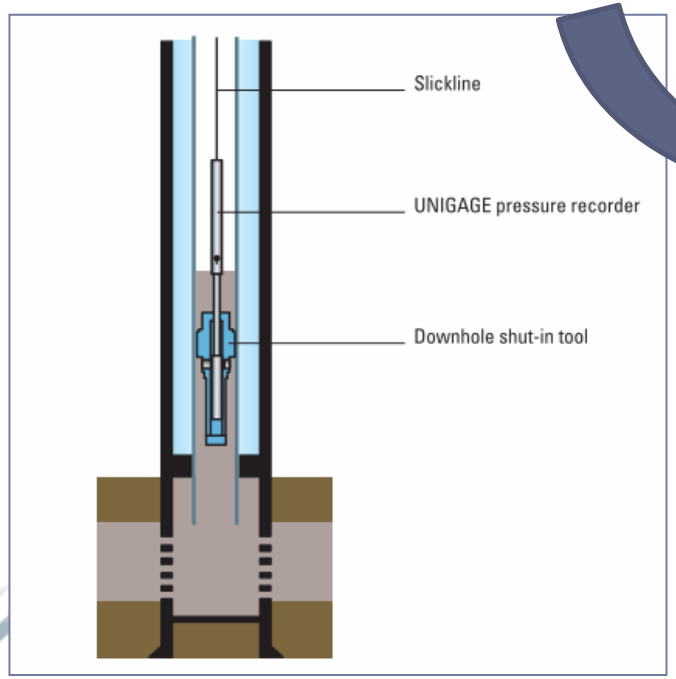
These examples are from Dajing Basin & incorporated downhole shut-in

# CHINA CSG DST #2

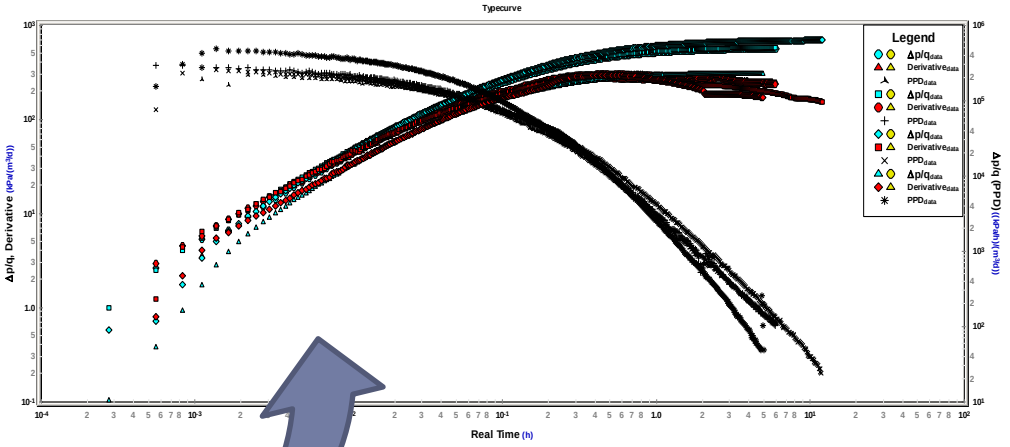
## 1. Design

- Cushion to keep BHP > Desportion Pressure
-Test duration based on expected low k of Dajing region
- Wellbore storage calculated assuming downhole shutin
- Ran commercial software simulation to find optimum design

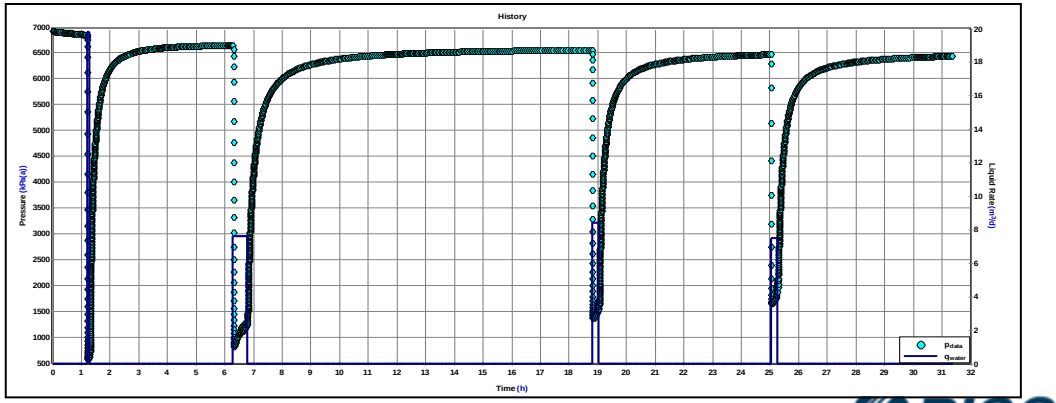
## 2. Execution with downhole shut-in



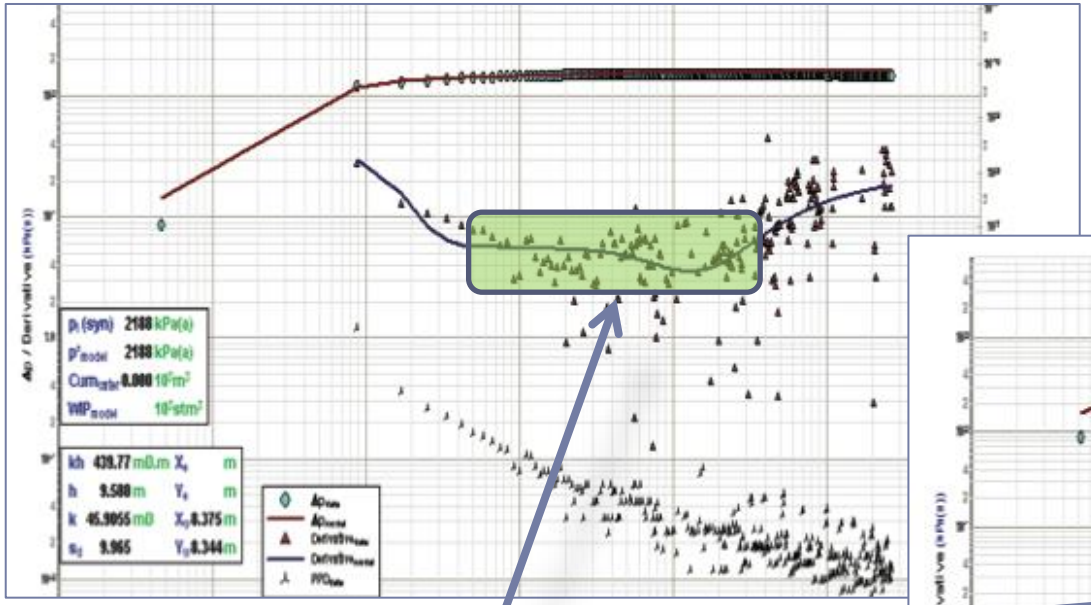

## 3. Analysis: Repeatable results

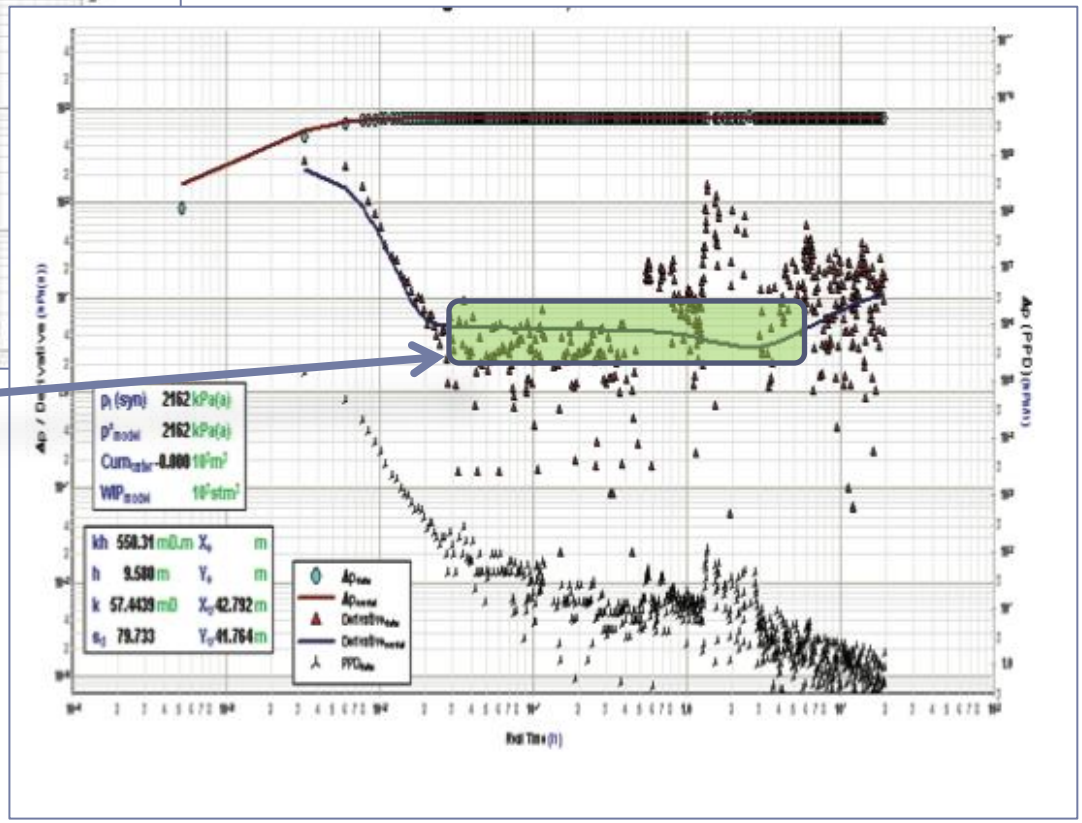



## 2. Data Collection: Quality pressure & rate measurement



# RECOGNIZE UNCERTAINTY IN PTA





Permeability in these examples could potentially range by a factor of 10.

Reliability in PTA improves with repeatability.

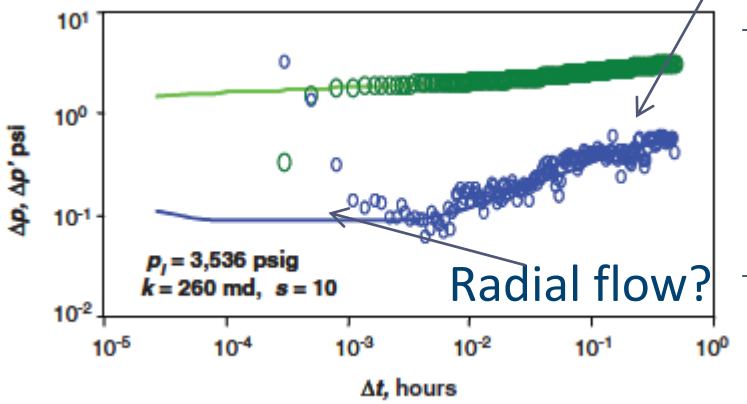
PTA should be regular part of reservoir management plan.

# INTEGRATE OTHER DATA SOURCES

Malasian work incorporated seismic data which indicated that the well was in close proximity to intersecting faults.


First Option

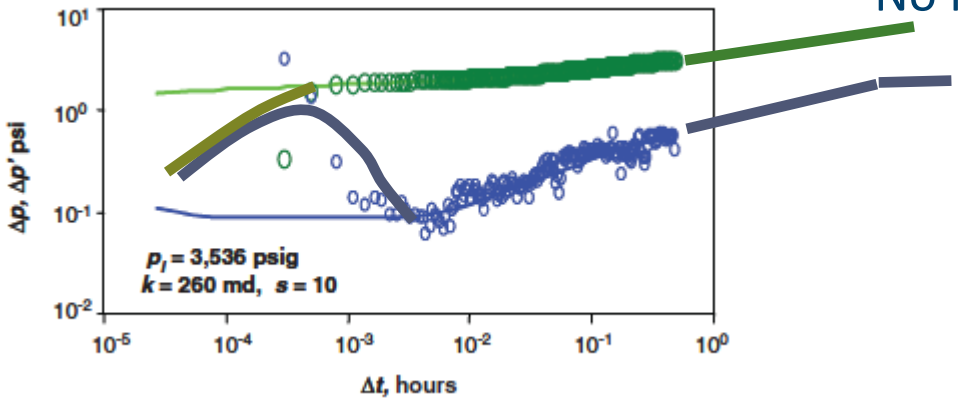
Boundaries flow




Original data & model

Second Option

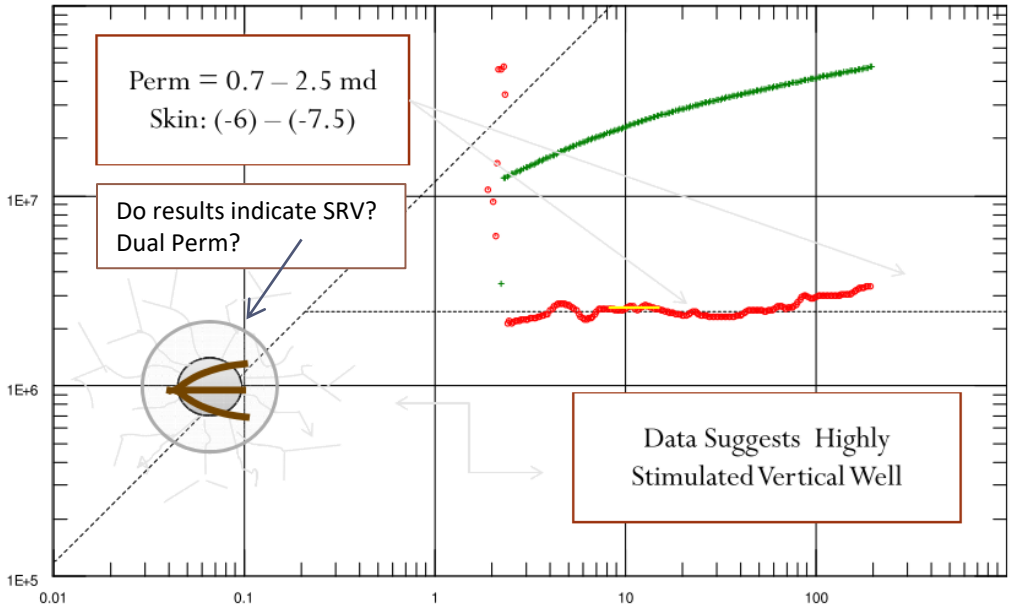
Lower permeability?
No fault?



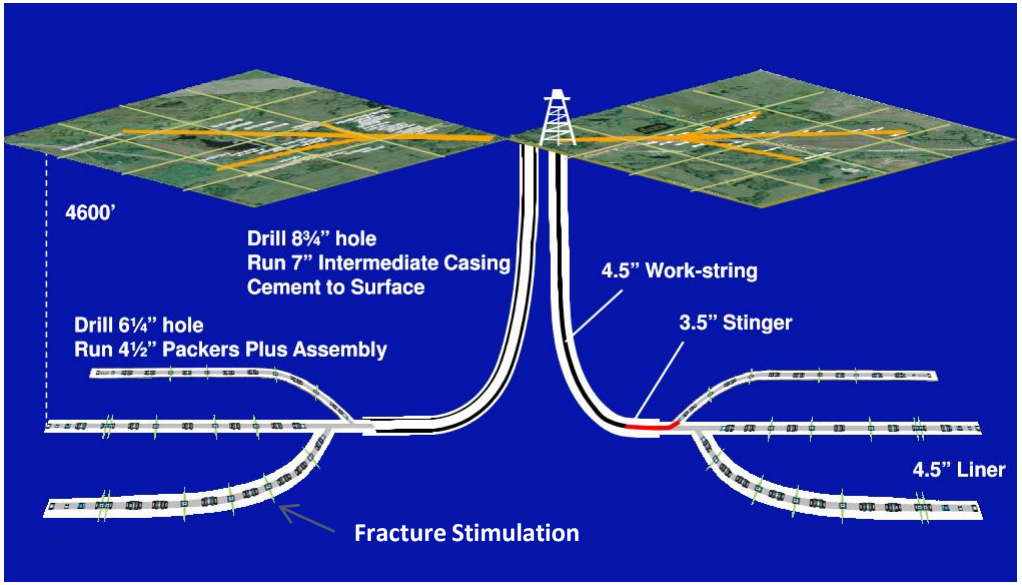
# 4 PRESSURE TESTING IN COMPLEX SITUATIONS

DECISIONS WITH CONFIDENCE

# COMPLEX WELLS (MANNVILLE CBM, CANADA)

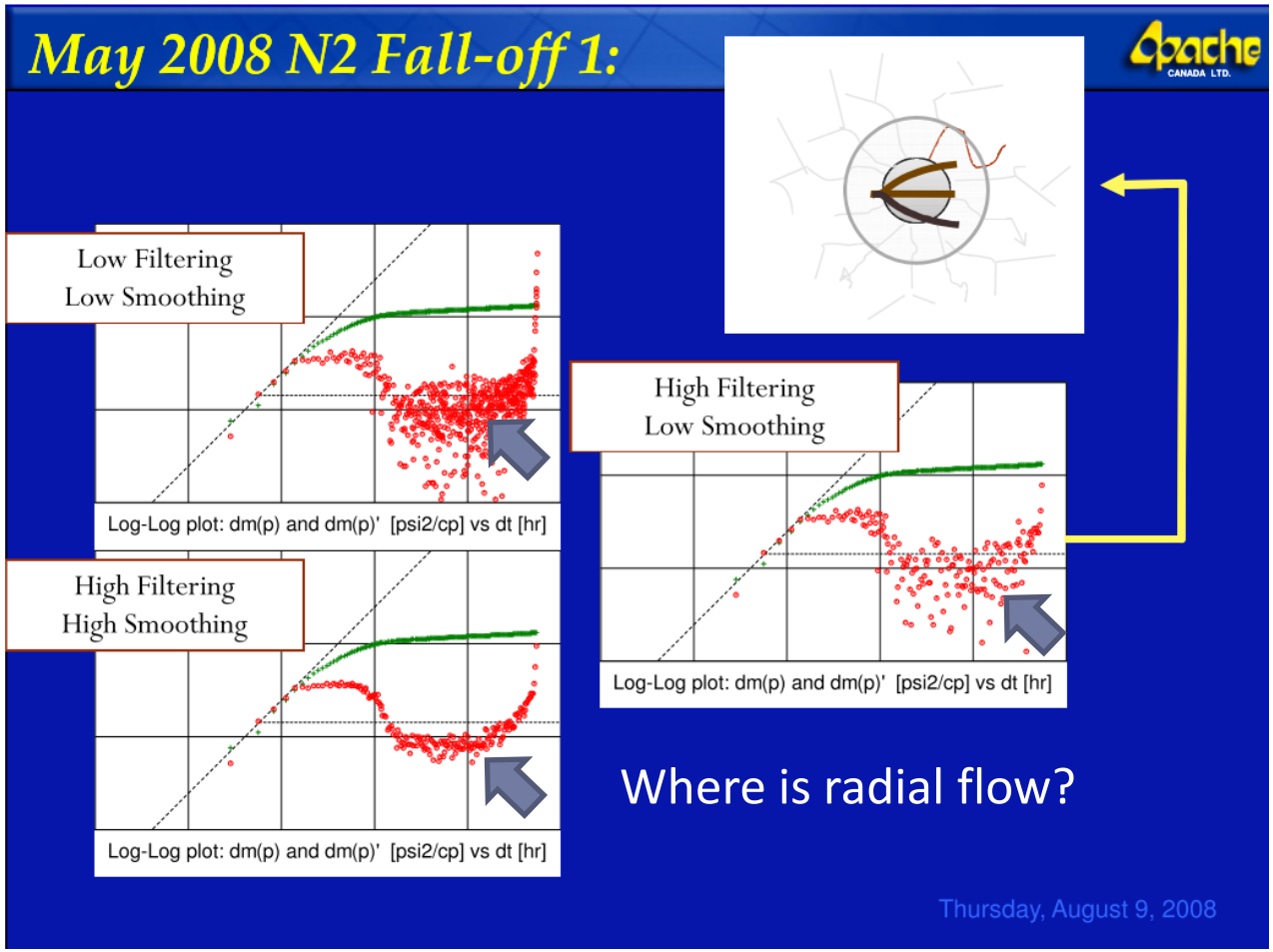



Log-Log plot: m(p)-m(p@dt=0) and derivative [psi2/cp] vs dt [hr]




What flow regimes are expected?
Stimulated rock volume?
Can we still do production forecast with $k_{eff}$?
Does $k_{eff}$ represent effective Productivity Index?
Were laterals isolated during testing?
How do we resolve k, skin, and Le?

# CSG STIMULATED WITH N2




Nitrogen DFIT's were performed on Mannville CSG

Wells were stimulated with nitrogen.

Nitrogen flow-back data was analysed, post closure.

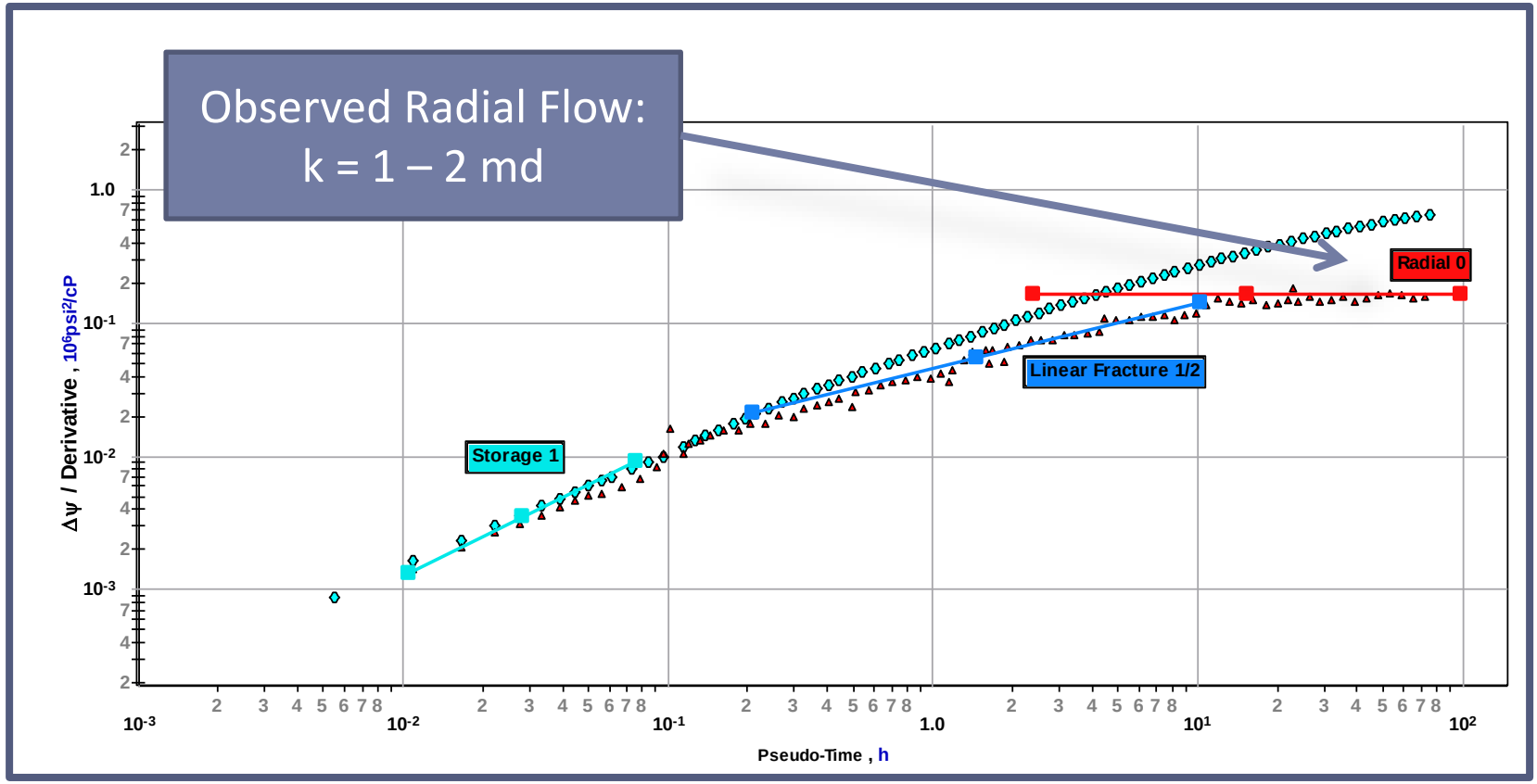
# 5

# TEST DURATION GUIDELINES

DECISIONS WITH CONFIDENCE

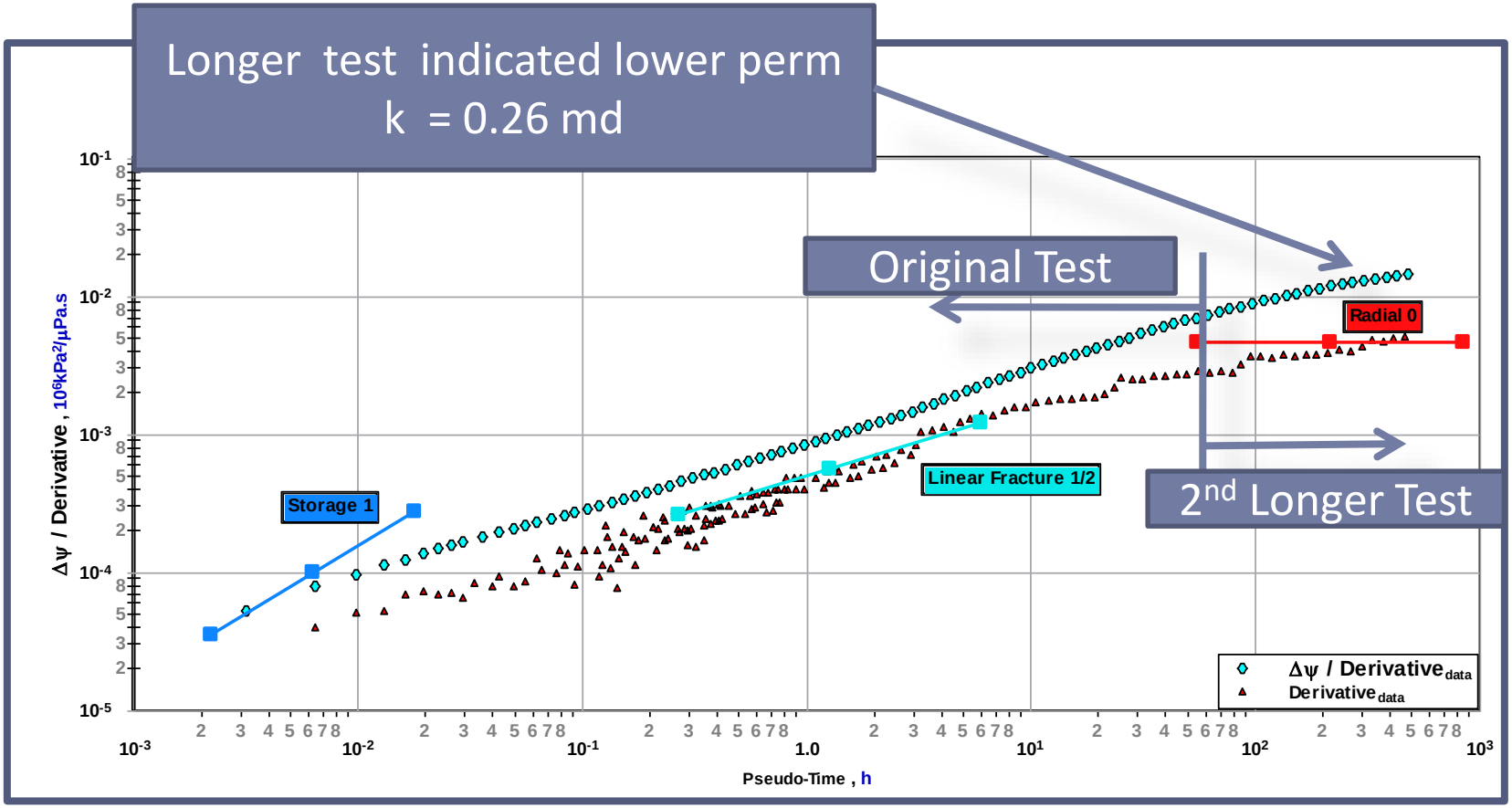
# HOW MUCH TIME DO WE NEED #1?

## Canadian unconventional gas example

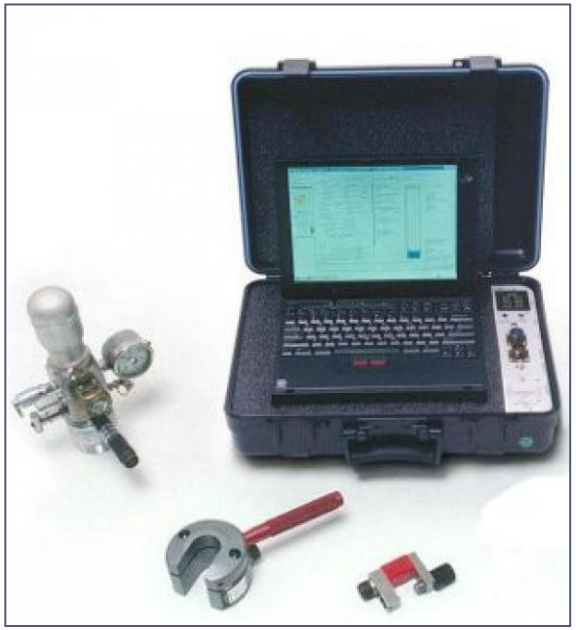


# HOW MUCH TIME DO WE NEED #2?

## Canadian unconventional gas example



# ACOUSTIC WELL SOUNDER



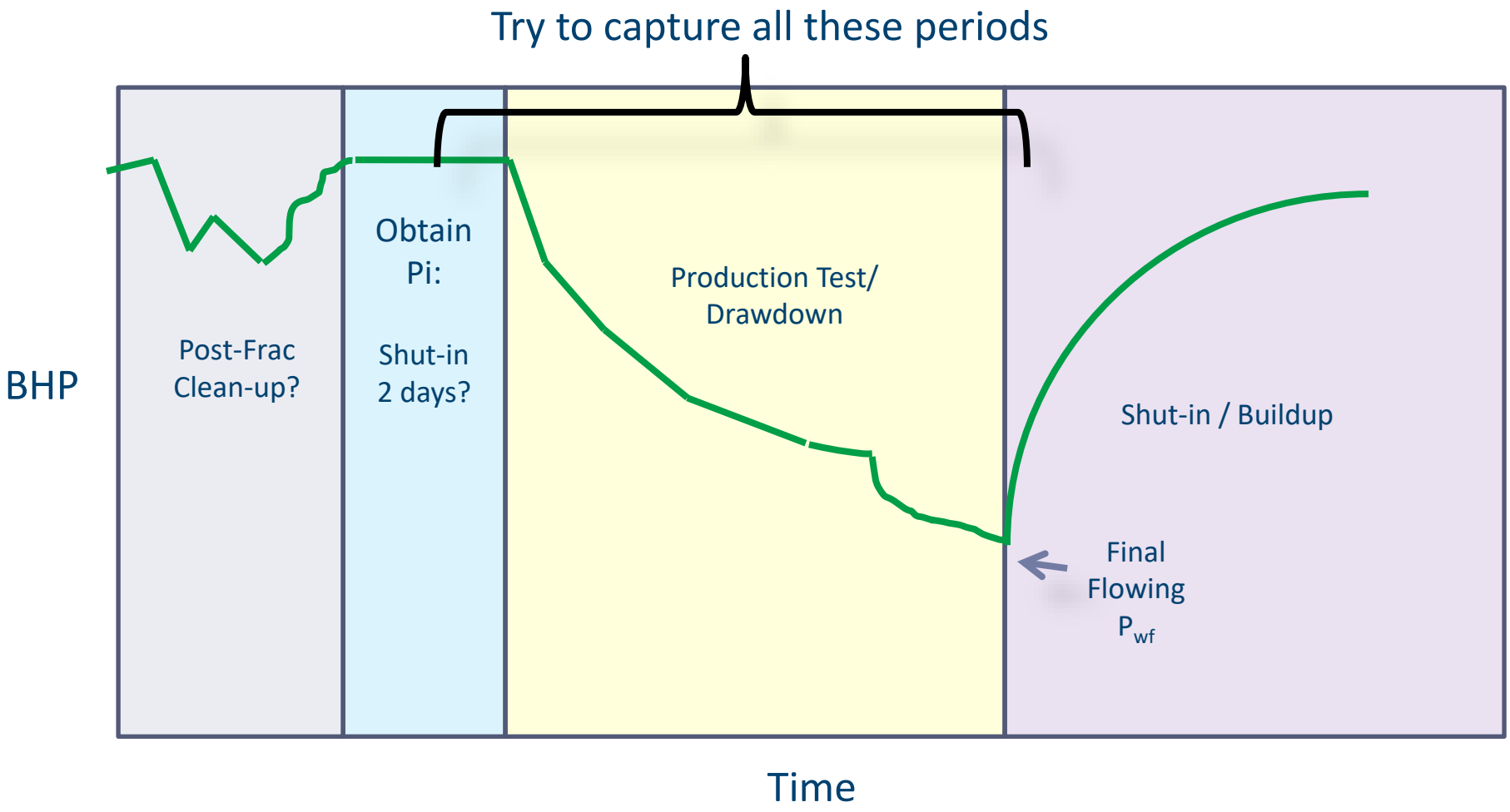
Computerized instrument for collecting liquid level data, and used to calculate BHP.

- Low Cost
- Can be used to provide semi-real time analysis
- Could potentially be used in tandem with downhole recorders

# 6 QUALITY CONTROL : GENERAL TESTING GUIDELINES

DECISIONS WITH CONFIDENCE

# IDEALIZED TESTING RECOMMENDATION GENERIC TO ALL TEST

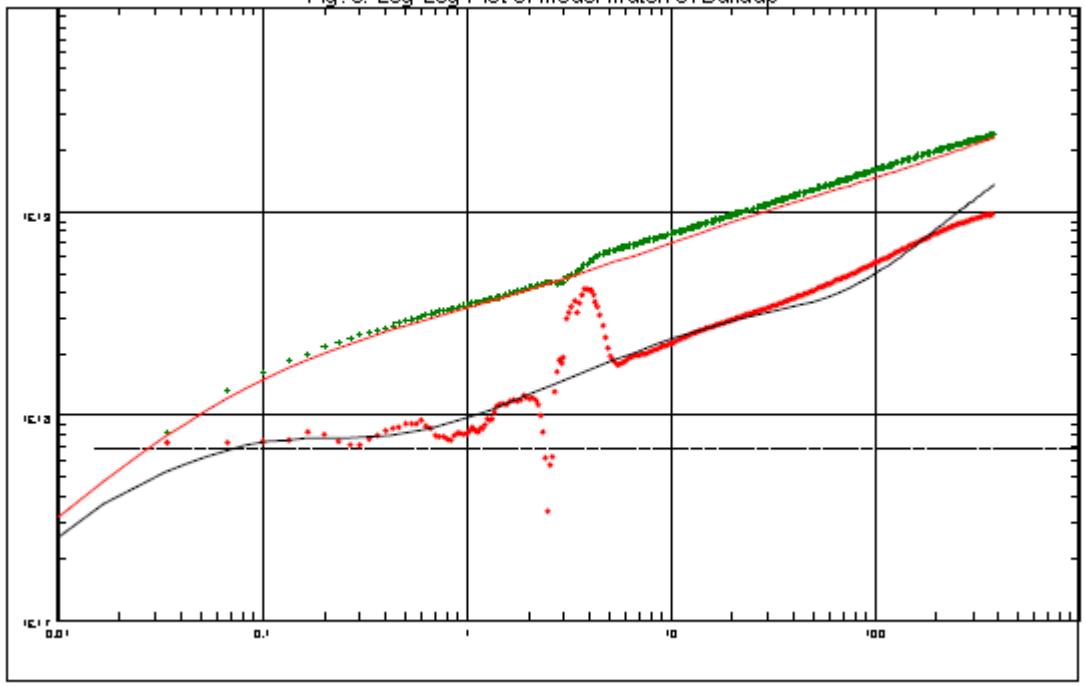


# INITIAL AND FINAL STATIC GRADIENTS

Static gradients and initial pressure

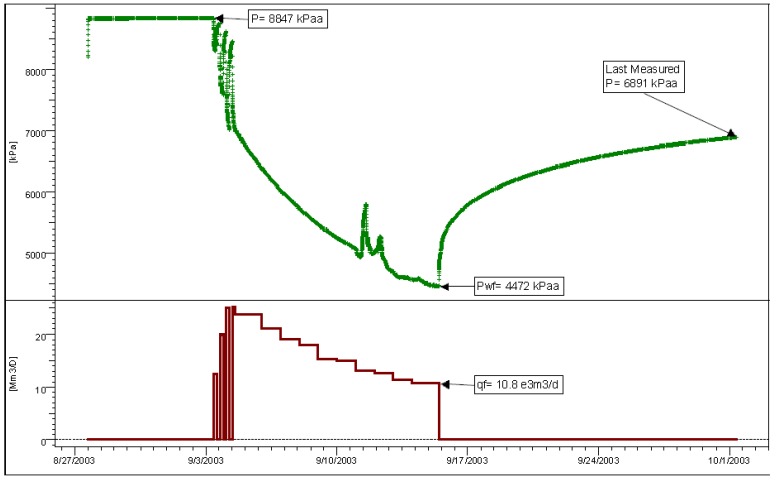
Buildup derivative soleley fracture or bilinear flow, however, permeability and/or boundaries must be constrained if we honor initial pressure

Fig. 3: Log-Log Plot of Model Match of Buildup



Log-Log plot: dm(p) and dm(p)' [kPa2/cp] vs dt [hr]

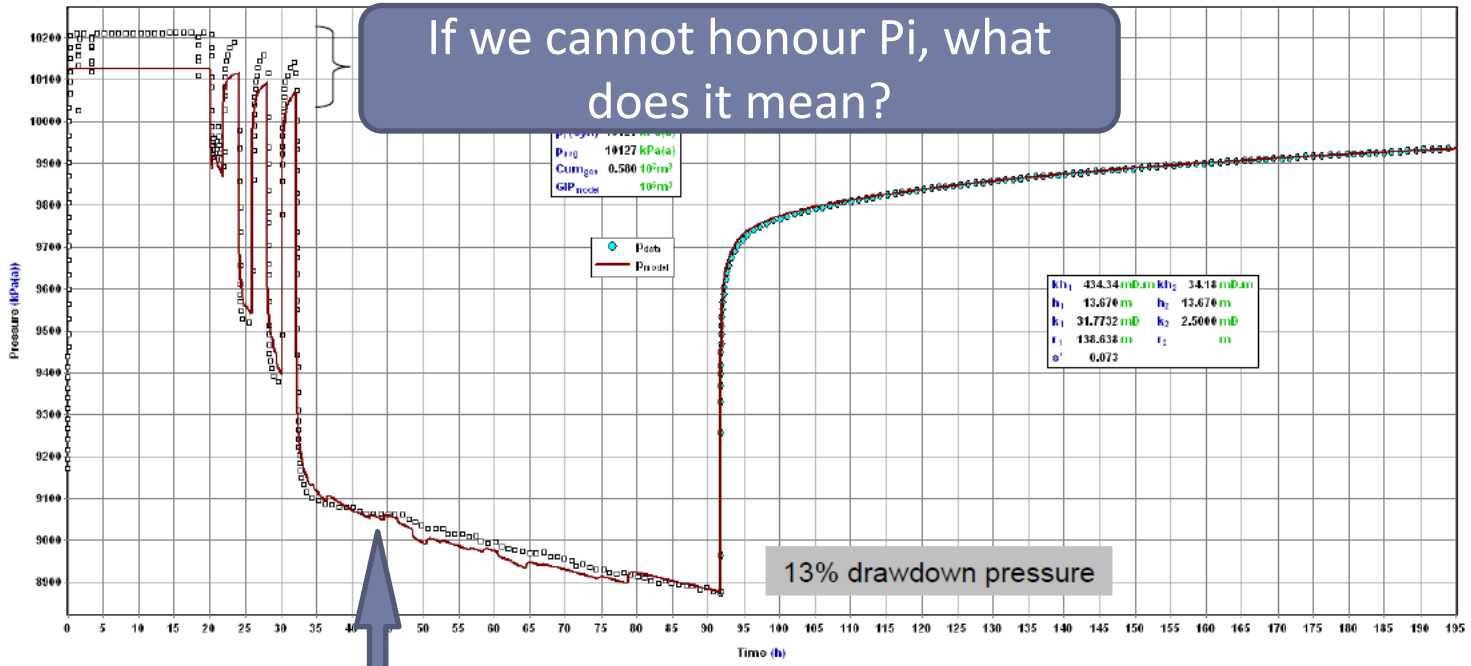
100/16-17-024-03W4/0




History plot (Pressure [kPa], Gas Rate [Mm3/D] vs Time [hr])

# WHY INITIAL RESERVOIR PRESSURE?

Work with all data! Any pressure-rate data can be potentially analyzed




Limited reservoir? Permeability decreasing away from wellbore ?

Production period can be analysed as well.
Linear trend may suggest PSS

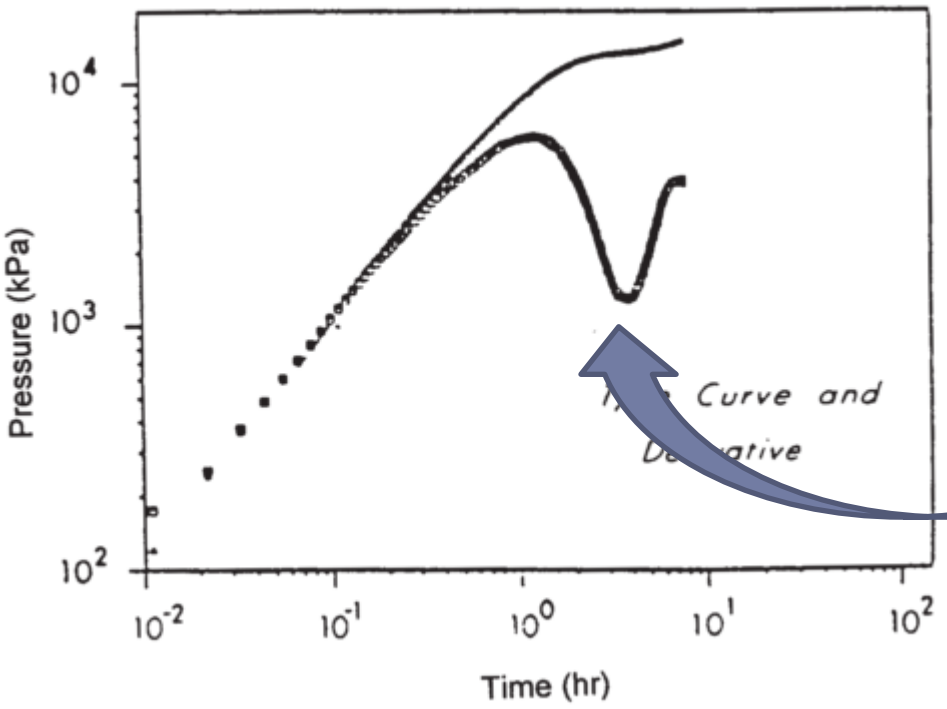
7

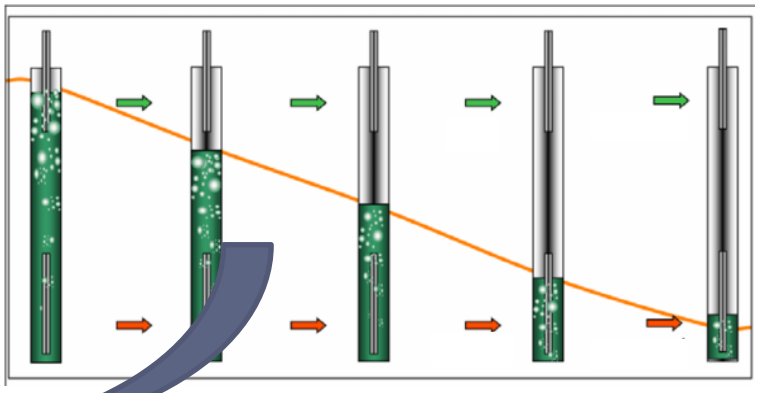
# WELLBORE DYNAMICS: RESERVOIR VS. WELLBORE

DECISIONS WITH CONFIDENCE

# DUAL POROSITY OR OTHER?

Liquid moving past recorders signature is very reminiscent of dual porosity one might expect in CBM reservoirs

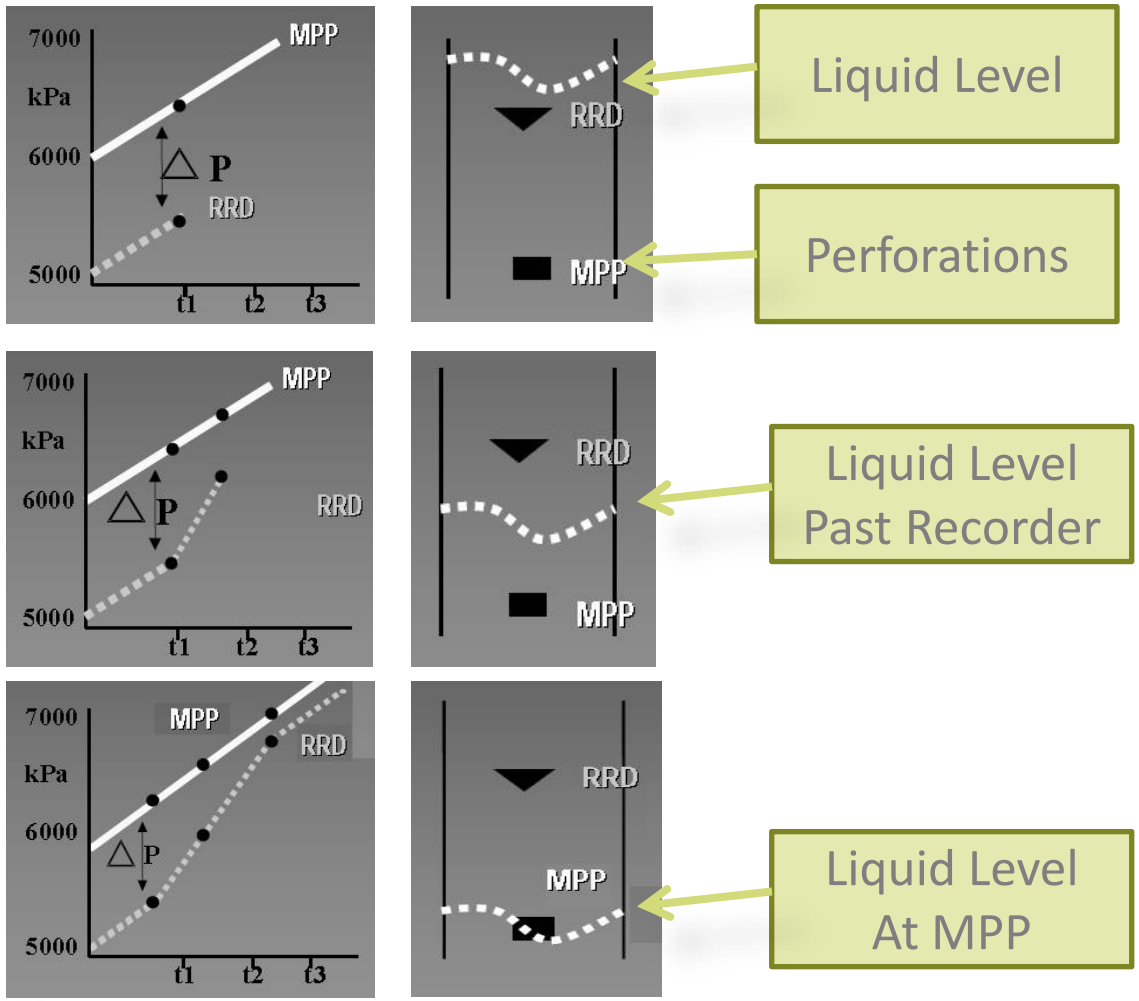


Upper Gauge

Lower Gauge

# CHANGING LIQUID LEVELS




Tandem recorders as well as initial & final static gradients can help indentify moving liquid levels

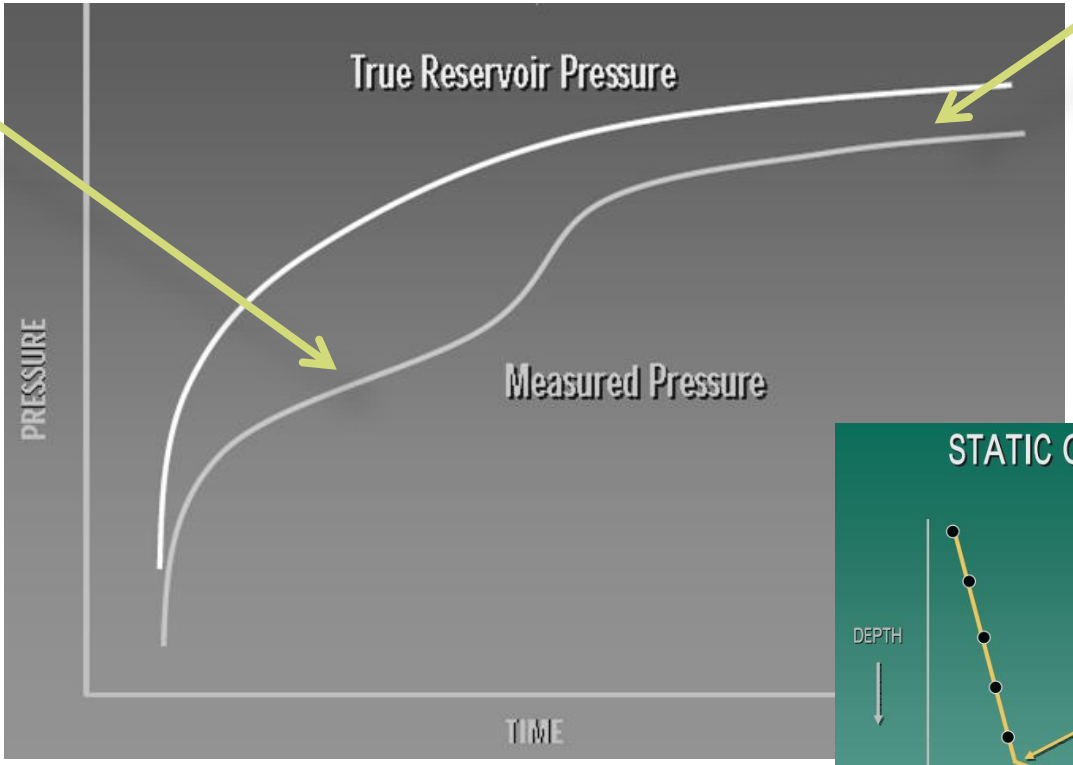
Mattar, L. (n.d.). Wellbore Dynamics in Well Testing. *SPE Distinguished Lecturer Program*.

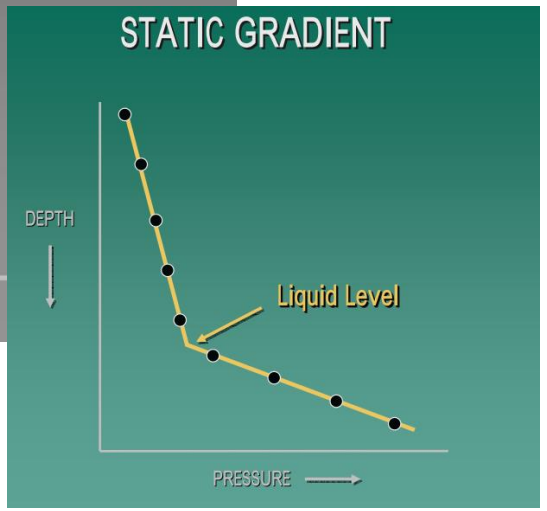
# CHANGING LIQUID LEVELS

Tandem recorders and static gradients

Gas Gradient

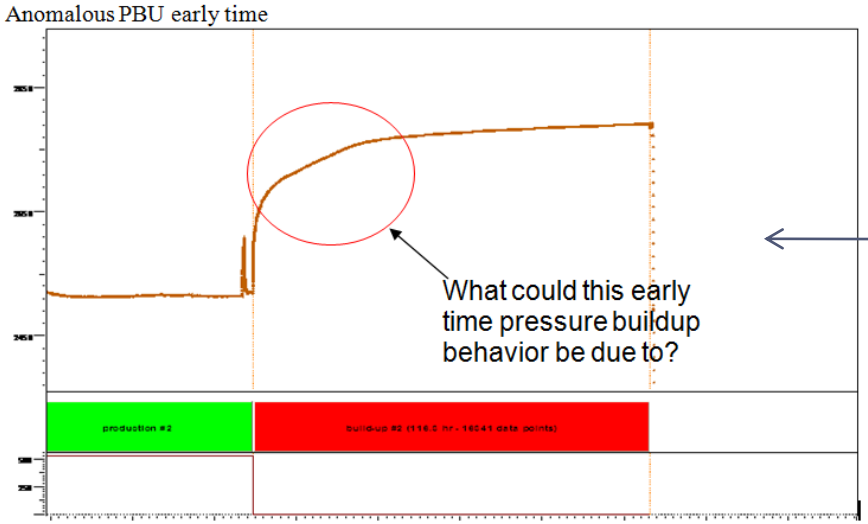
Liquid Gradient

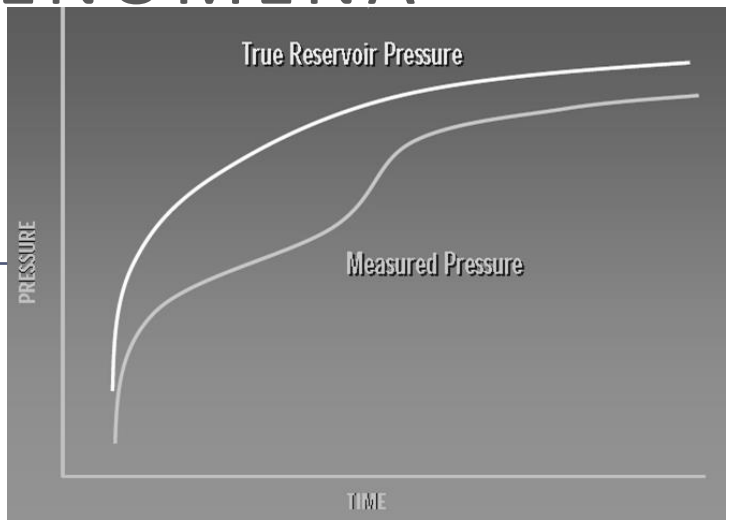


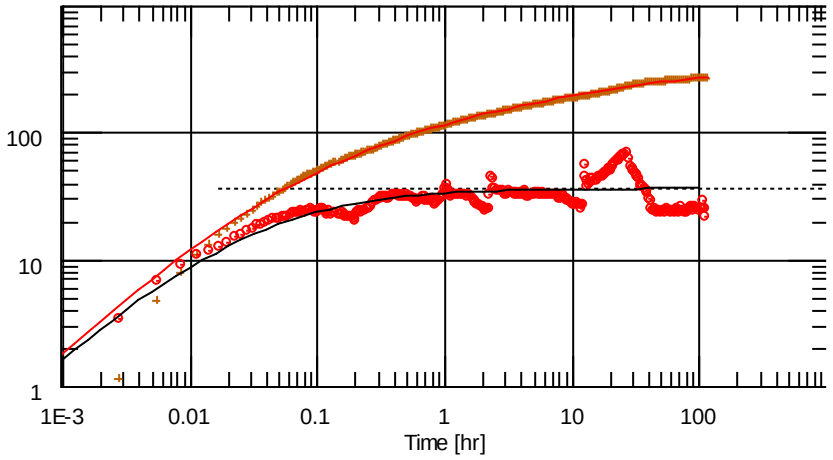




Mattar, L. (n.d.). Wellbore Dynamics in Well Testing. *SPE Distinguished Lecturer Program*.

# LAYERING? OR OTHER PHENOMENA




Well Testing Discussion Forum: Anomalous PBU Early Time

Close

Open | Reply | Edit Item | Alert Me

| | |
|---|---|
| **Subject** | Anomalous PBU Early Time |
| **Body** | Dear Forum folks:<br><br>I am looking at possible reasons for the change in the pressure response while the well is shut-in (see attached).<br>This is a vertical well. The gauges are at 900ft above the perforations. The perforations cover multiple reservoir layers.<br><br>What could be reasons for the pressure (cartesian plot) and the pressure derivative behaviour?<br><br>appreciate your ideas.<br><br>regards<br>Tony |
| **SPE Created** | 01-Jul-2012 |
| **SPE Posted By** | MR Tony Thomas, SPEC |
| **Approval Status** | Approved |
| **Attachments** | Anomalous PBU early time.doc |

Content Type: Discussion
Created at 7/1/2012 6:20 AM by Mr. Tony Thomas, SPEC
Last modified at 7/2/2012 12:08 AM by Miss Madhavi Vitthal Jadhav

Close

Edited: 7/9/2012 11:53 AM by Ms. Yan Pan — View Properties | Reply

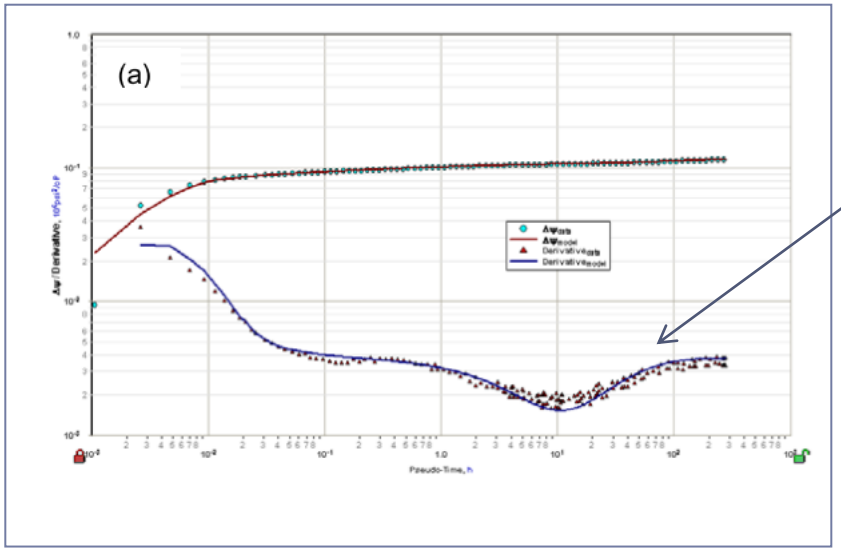
It is not the layered behavior that was causing the anomaly. If it were, you would not be able to tell from any of the history, semi-log or log-log plots - these plots would have been as smooth as a homogeneous system. As suggested by some others, it was indeed due to phase segregation and changing fluid-interface level.

Dr. N M Anisur Rahman — Approved

# DUAL POROSITY OR OTHER?

Is this really CBM dual porosity behaviour?

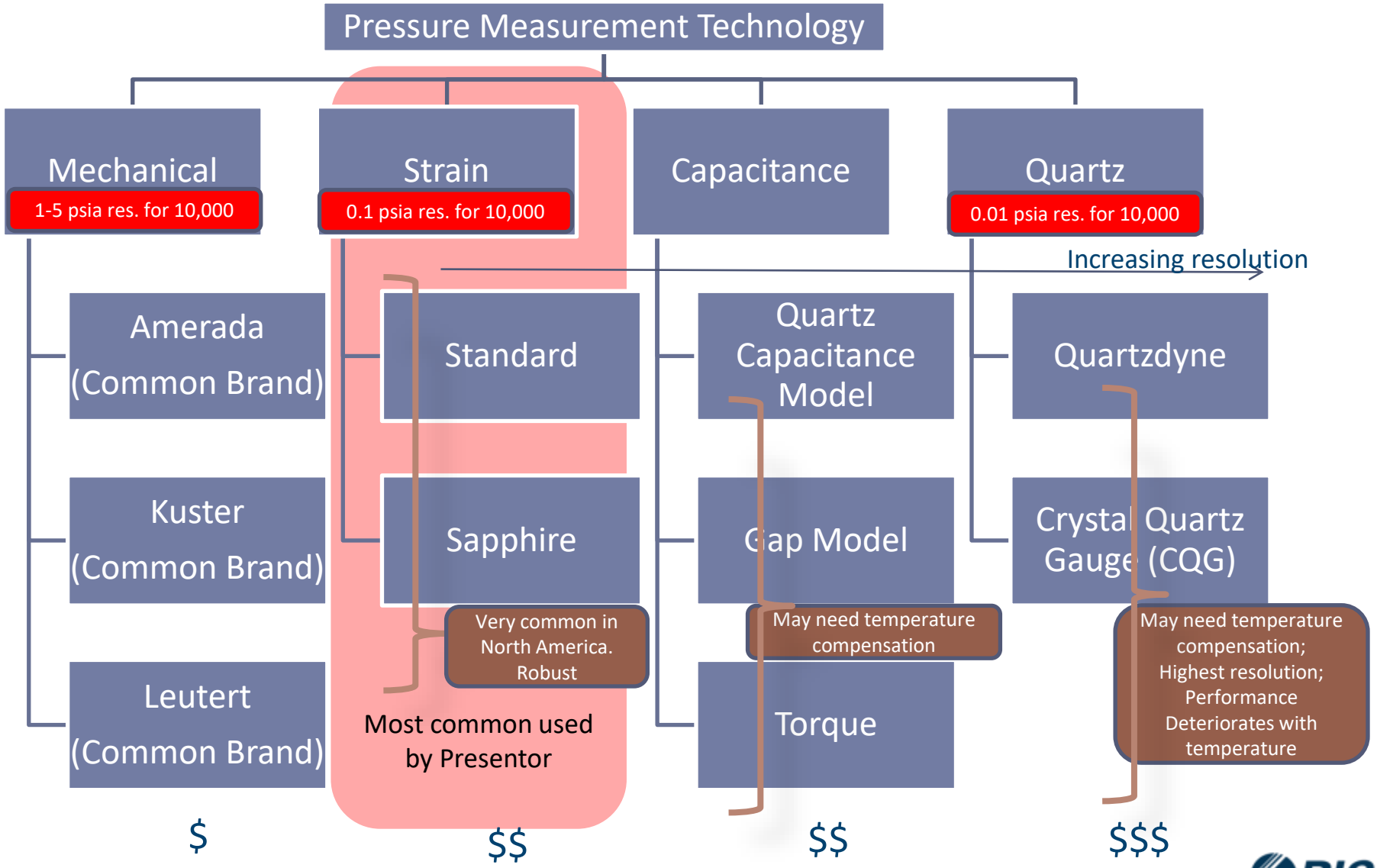
Example from Canadian Horseshoe CBM (Dry coals)




Dual porosity?
Smoothing?
Filtering?
How confident are we in the interpretation?

Clarkson, C. R. (2008)

# SOME BASIC GAUGE TYPES

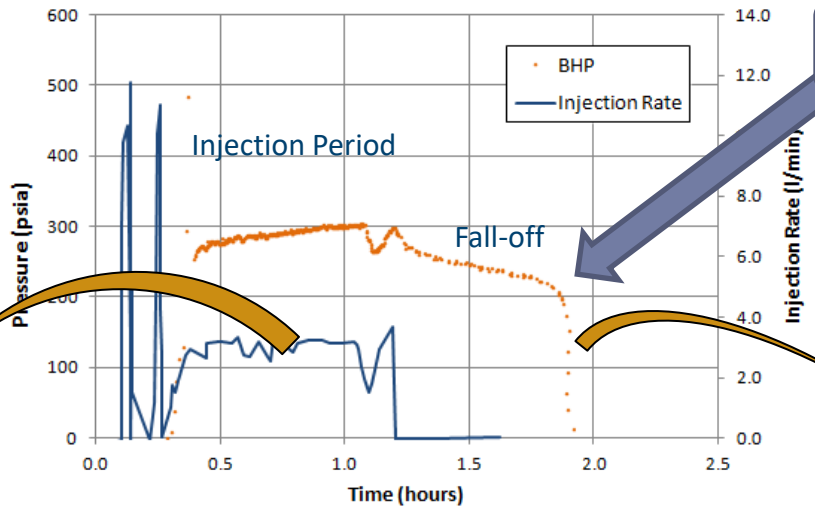


8

# EVEN BAD DATA CAN BE USEFUL
# FIELD EXAMPLE:

DECISIONS WITH CONFIDENCE

# IFO TEST FAILURE: INDONESIAN CSG

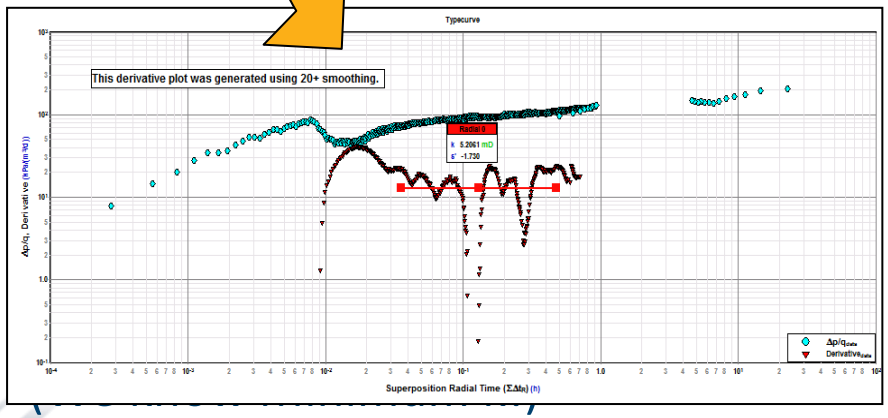



Leak?

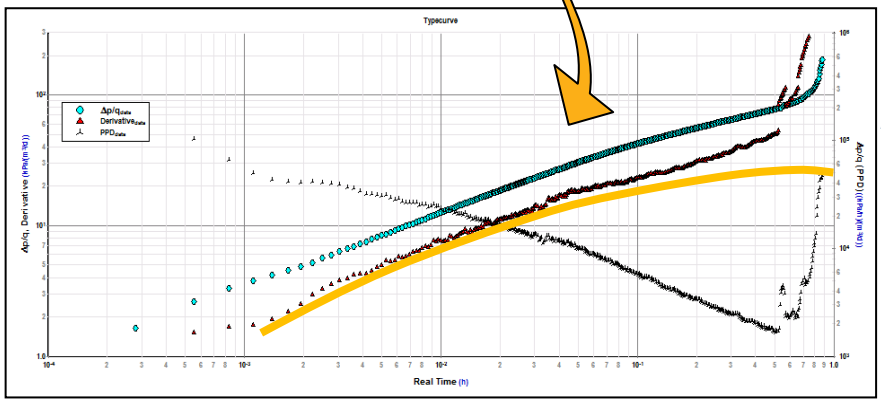
What impact would a leak have on PTA analysis?

Rate of pressure decline is not stabilising?

Analyse Injection




Analyse Buildup




Actual

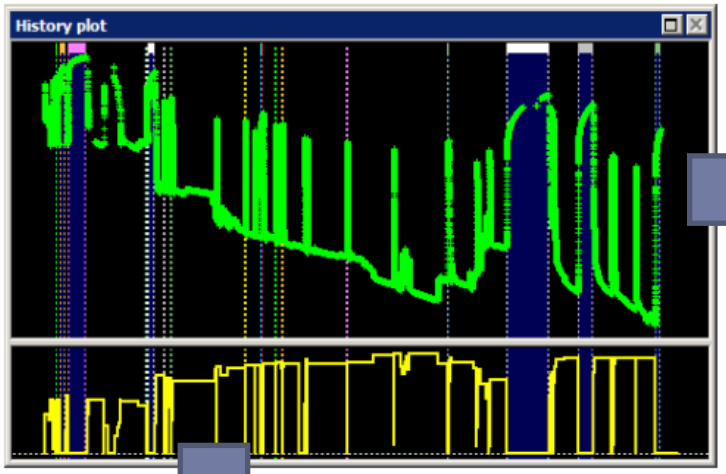
Ideal

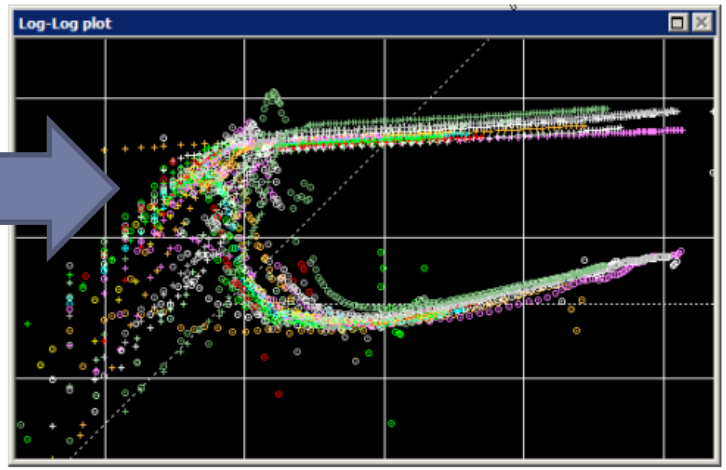
# 9 FUTURE OF TESTING

DECISIONS WITH CONFIDENCE

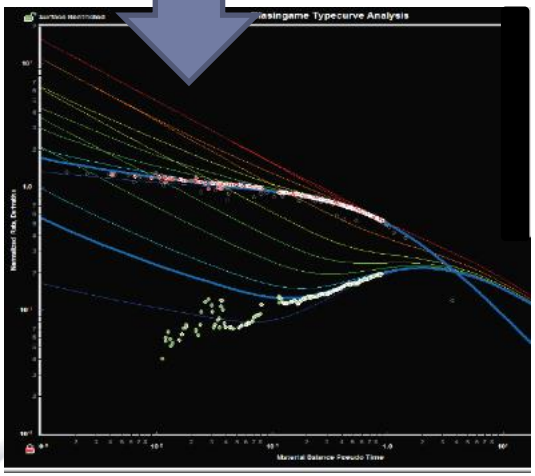
# PERMANENT DOWN HOLE GAUGES

- Allows easy integration of common data set between PTA/PA and reservoir modelling

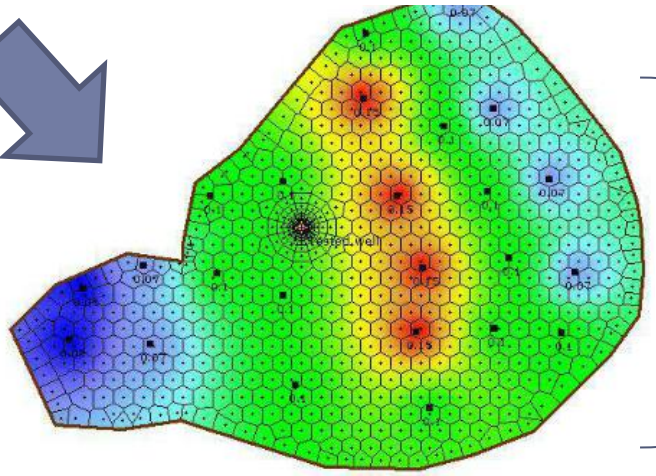



Analysis of shut-in data



Analysis of rate data

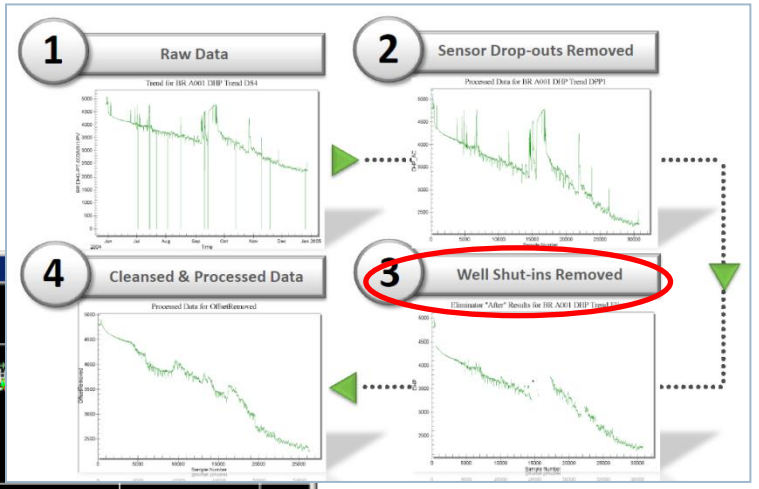


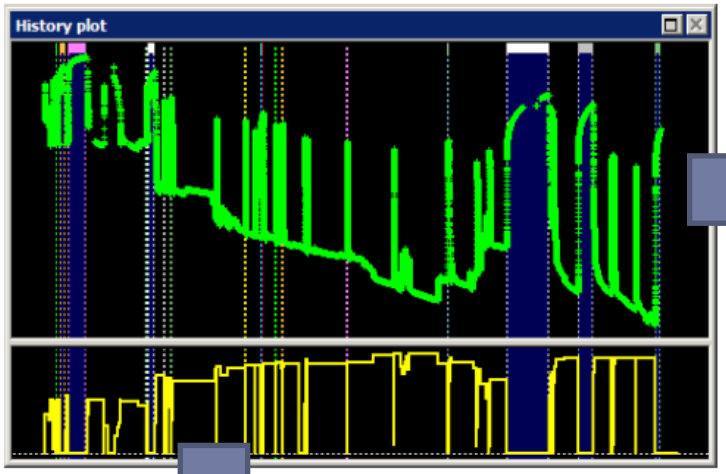
A coherent model linked by common platform

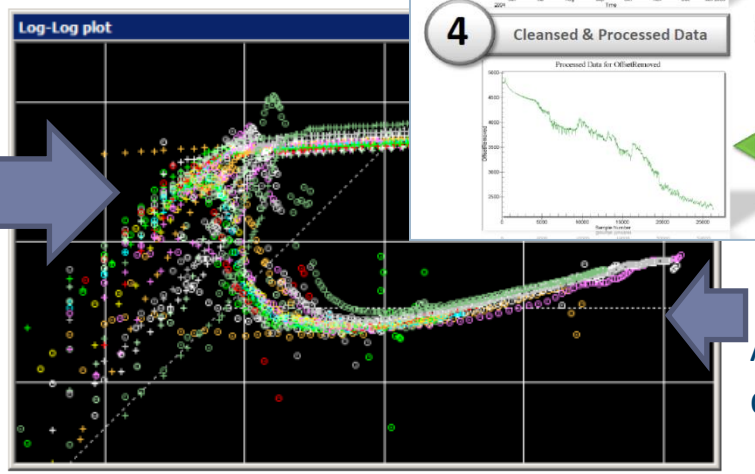
Changing skin/kh Boundaries

# DATA MANAGEMENT

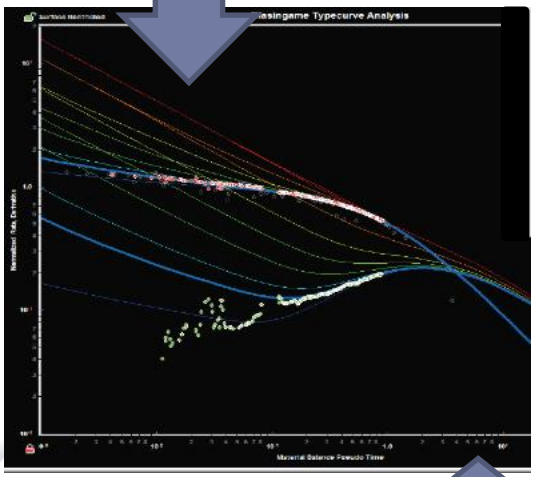
Some SCADA systems remove shut-in data!



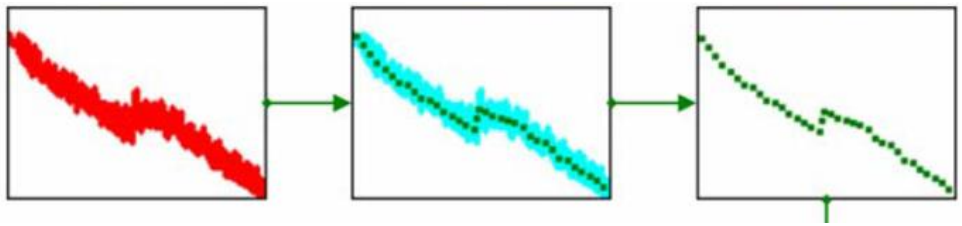




Analysis of shut-in data



Analysis of rate data



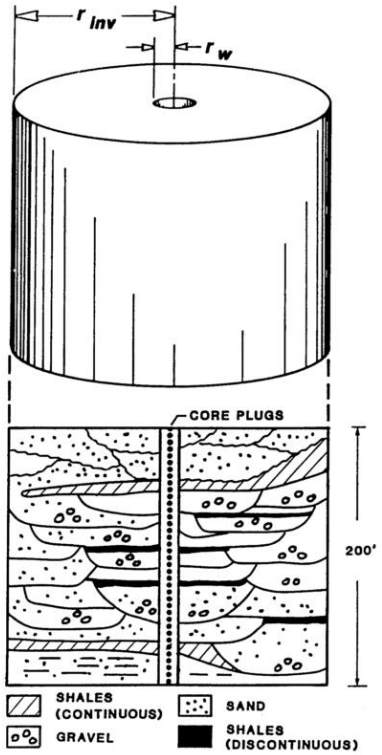
Filtering of data occurs at all levels of PA and PBU

PA: 1 point / hour

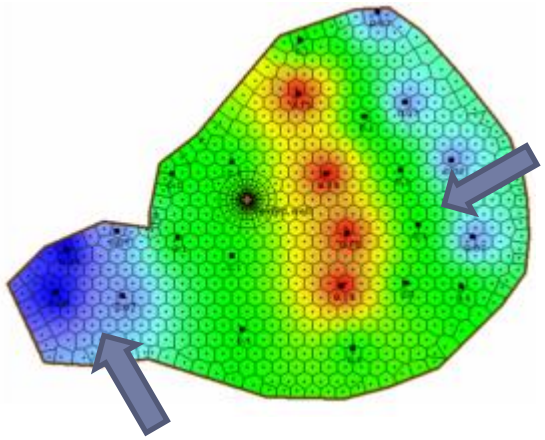
PBU: 1000 / hour

# OTHER REMARKS: PTA VS. RTA

Pressure transient analysis:
wellbore permeability & skin




Rate transient analysis:
Wellbore drainage area, pool size



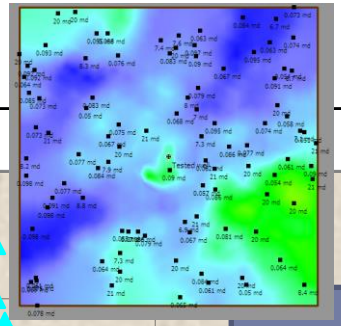
Pressure Disturbance

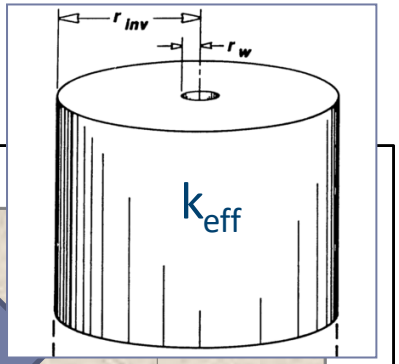
Virgin Pressure

Combined pressure and rate analysis provides more comprehensive reservoir description

# OTHER REMARKS: PTA VS. RTA

Perm Map
(Realization #1)






Average
Effective Perm

Time


Realization #1

Realization #2

Realization #3

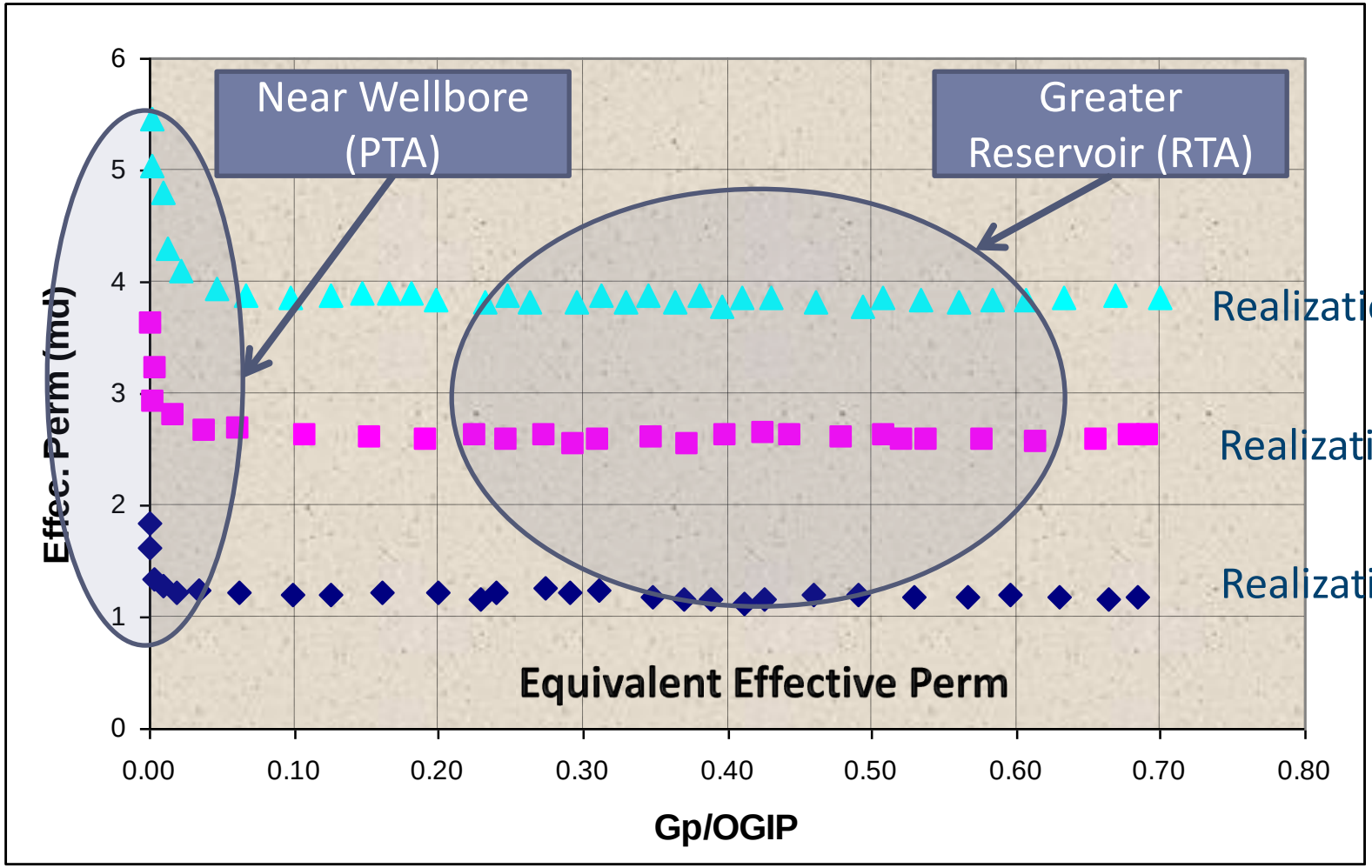
Effec. Perm (md)

0
1
2
3
4
5
6

0.00
0.20
0.30
0.40
0.50
0.60
0.70
0.80

Gp/OGIP

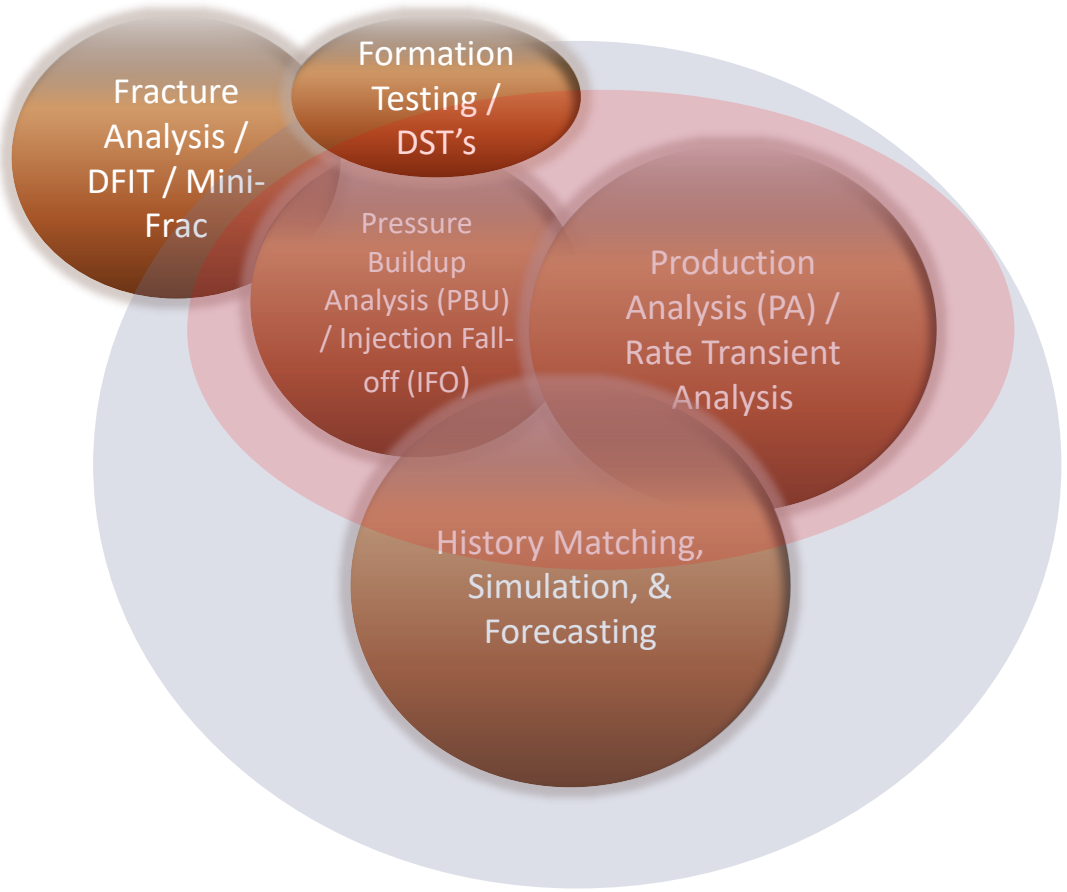
# OTHER REMARKS: PTA VS. RTA



# 10 CONCLUSION

# CONCLUSION

FINAL COMMENTS




Pressure and rate analysis are coalescing

Transient analysis is moving away from the wellbore, further into the reservoir

Integrated platforms, analysis methods, and tools are being deployed including:

Ecrin (Kappa Eng)

Harmony (Fekete Associates)

Not a comprehensive list

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*DECISIONS WITH CONFIDENCE*