Results Obtained from Reconnaissance-Level and Detailed Reservoir Characterization Methods Utilized for Determining Hydraulic Property Distribution Characteristics at Mountaineer AEP #1

FA. Spane [1], PD. Thorne [1], N. Gupta [2], P. Jagucki [2],
TS. Ramakrishnan [3], and N. Mueller [3]

(1) Pacific Northwest National Laboratory
(2) Battelle Memorial Institute
(3) Schlumberger-Doll Research

March 21, 2006
PNNL-SA-48622

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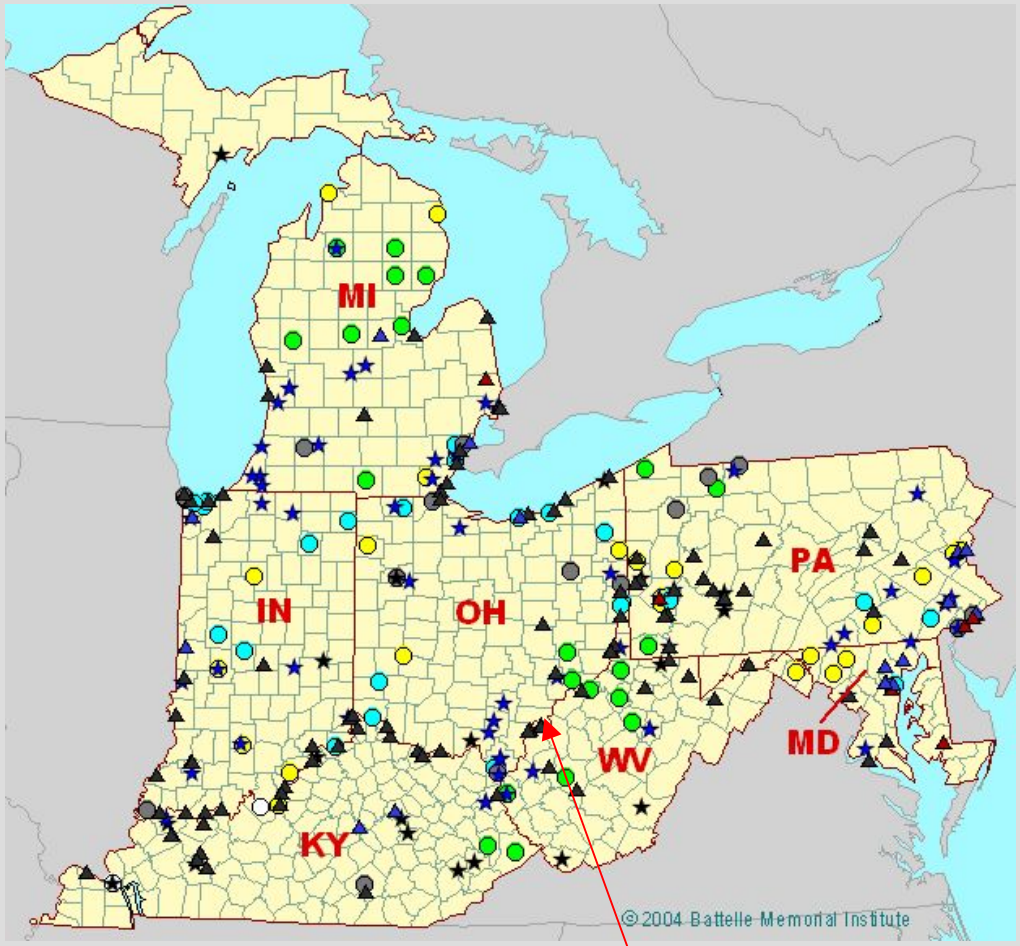
Presentation Outline

- Background Information
- Hydraulic Property Characterization Methods
  - Reconnaissance-Level
  - Detailed Test Techniques
- Test Results/Examples
  - Open Borehole
  - Reservoir Zones
    - Rose Run (Sandstone)
    - Copper Ridge (Dolomite)
- Summary/Conclusions

Mountaineer/Ohio River Valley CO_2 Storage Project Participants/Sponsors

- DOE/NETL
- American Electric Power
- Battelle Memorial Institute
- Schlumberger
- Pacific Northwest National Laboratory
- BP
- The Ohio Coal Development Office

Borehole Location



AEP #1

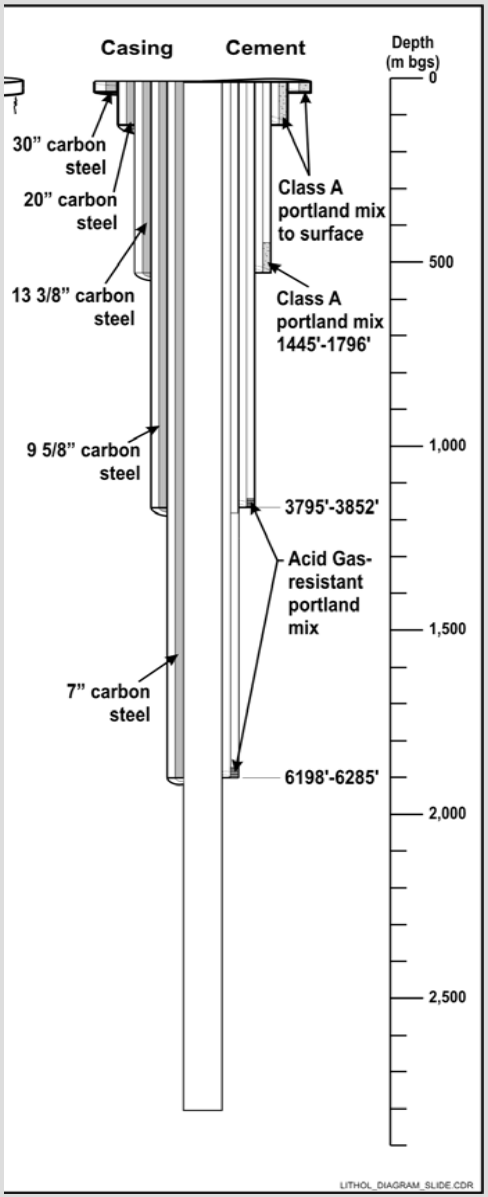
Legend

Power Plants
- Coal
- Nat. Gas
- Oil

Planned Power Plants
- Coal
- Nat. Gas

Other Industrial Plants
- Ammonia
- Cement
- Ethylene & Ethylene Oxide
- Gas processing
- Hydrogen
- Iron & steel
- Refineries

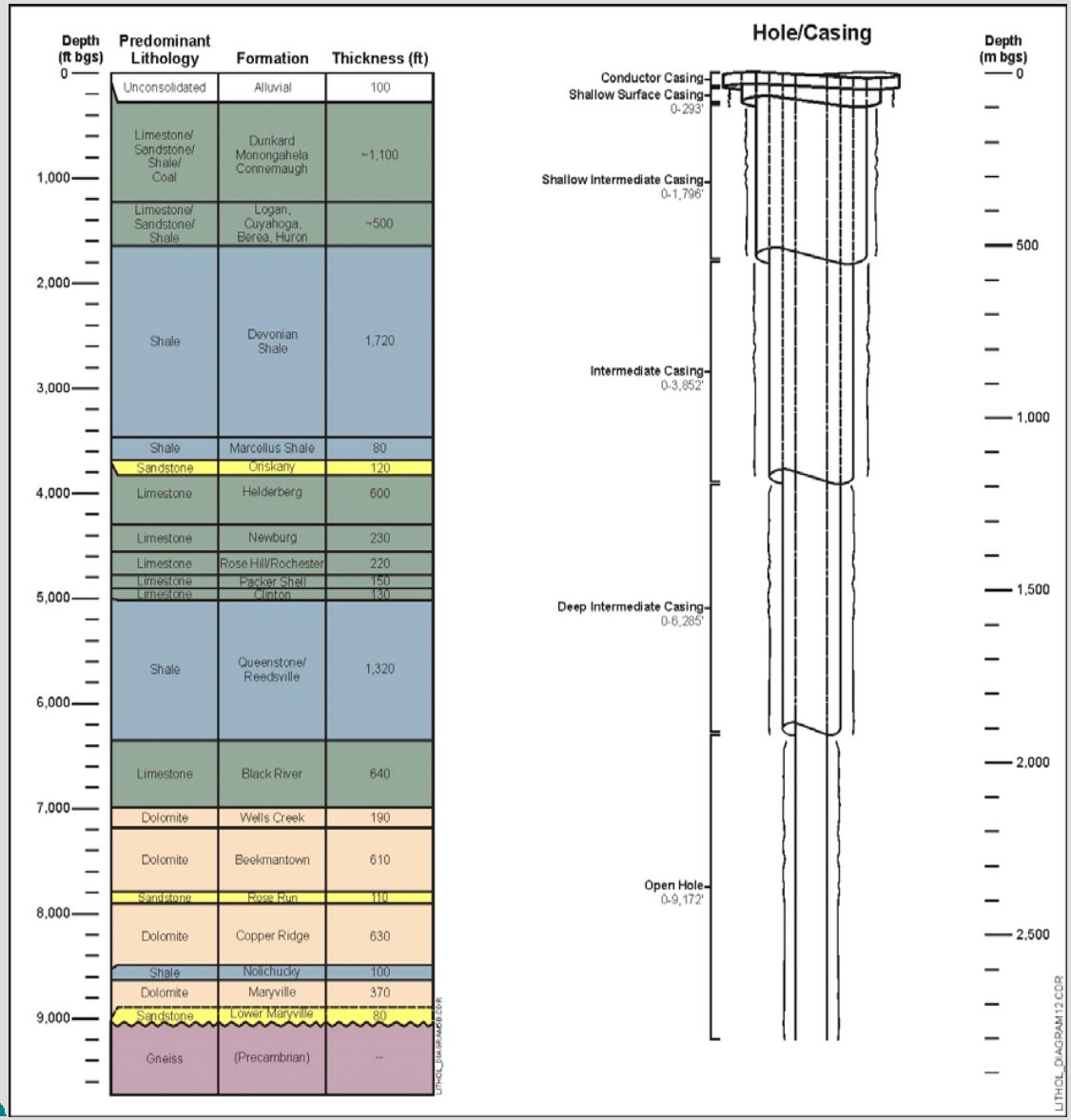
Borehole History/Testing Background



Background Information:

- Borehole drilled between May - July 2003
- Open-borehole section: 6,285 to 9,190 ft
  - 293 ft of core
  - 23 side-wall cores
- Borehole hydrologic testing:
  - March - April 2004
  - October 2005

Borehole As-Built/General Stratigraphy



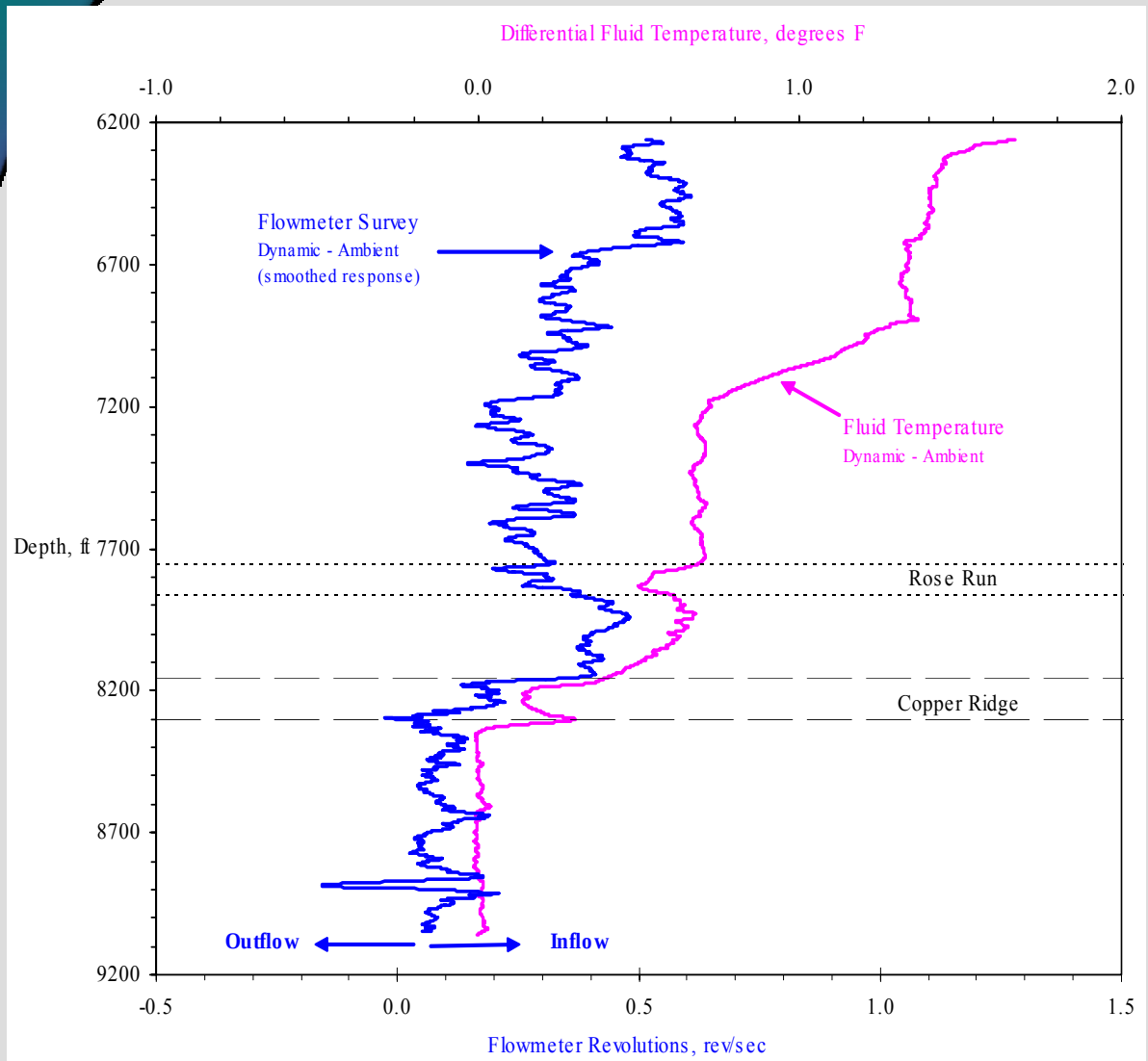
Open Borehole Reconnaissance-Level Techniques

- General Characteristics
  - Can scan large formation sections rapidly
  - Provides qualitative/quantitative information on permeability distribution
  - Small-scale of investigation
  - Affected by formation damage/well skin effects

AEP #1 Reconnaissance-Level Techniques Cont'.

- Reconnaissance Characterization Techniques
  - Wire-Line Methods
    - Nuclear Magnetic Resonance
      - CMR (Combined Magnetic Resonance)
    - Dynamic Fluid Flow Tests
      - Flowmeter
      - Fluid Temperature/Conductivity
  - Core Profile-Permeability Scan
  - Sequential/Composite Borehole Slug/DST Tests

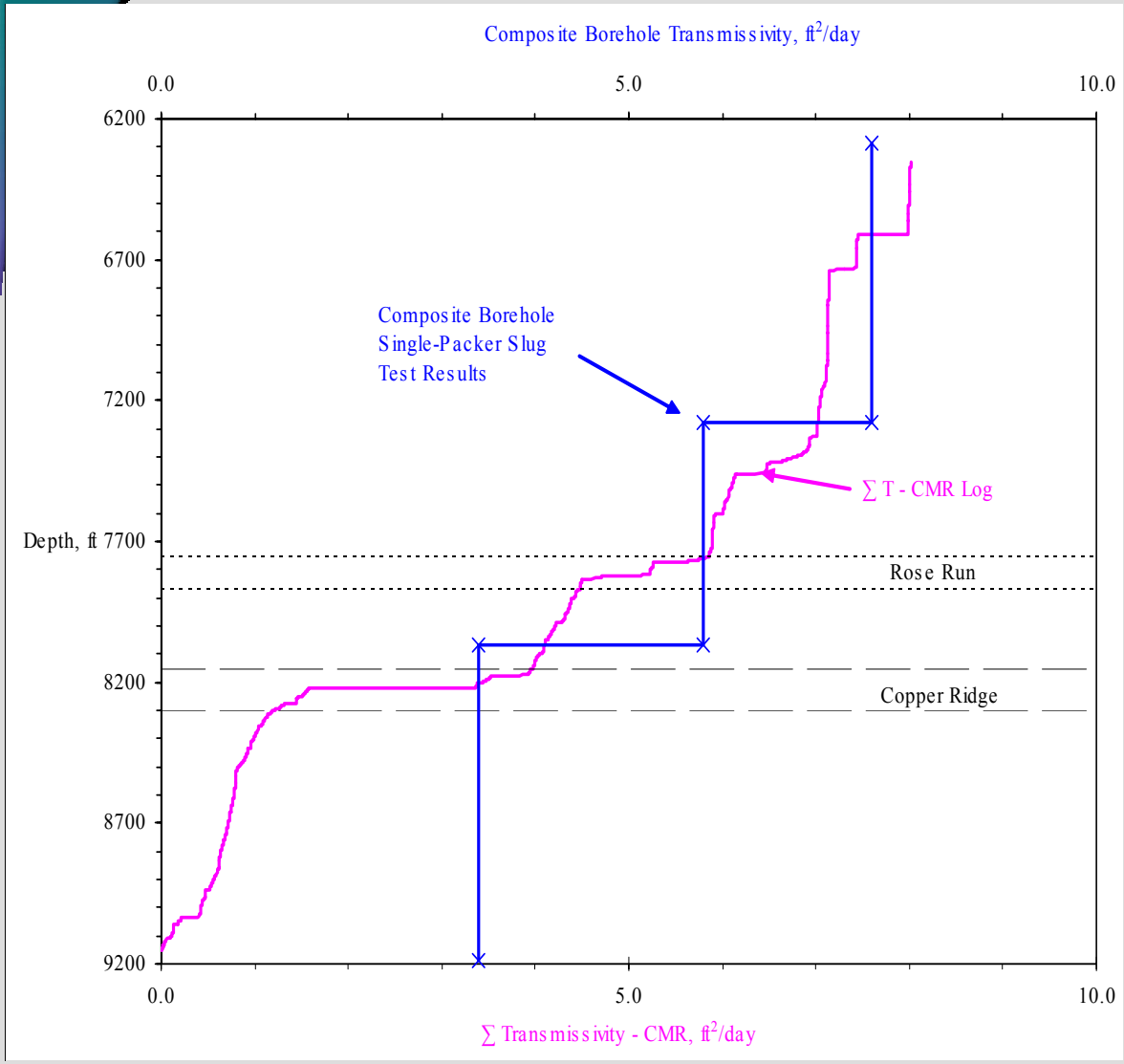
Open Borehole: Dynamic Fluid Flow Test Results



General Findings:

- Little formation fluid inflow below 8,320 ft
- Significant inflow/outflow zones within the Copper Ridge and Rose Run Formations

Open Borehole: CMR and Composite Slug Test Results



General Findings:

- Relative correspondence between composite slug tests and converted summation CMR results
- Correspondence lends credence to the continuous vertical distribution depicted by the CMR survey

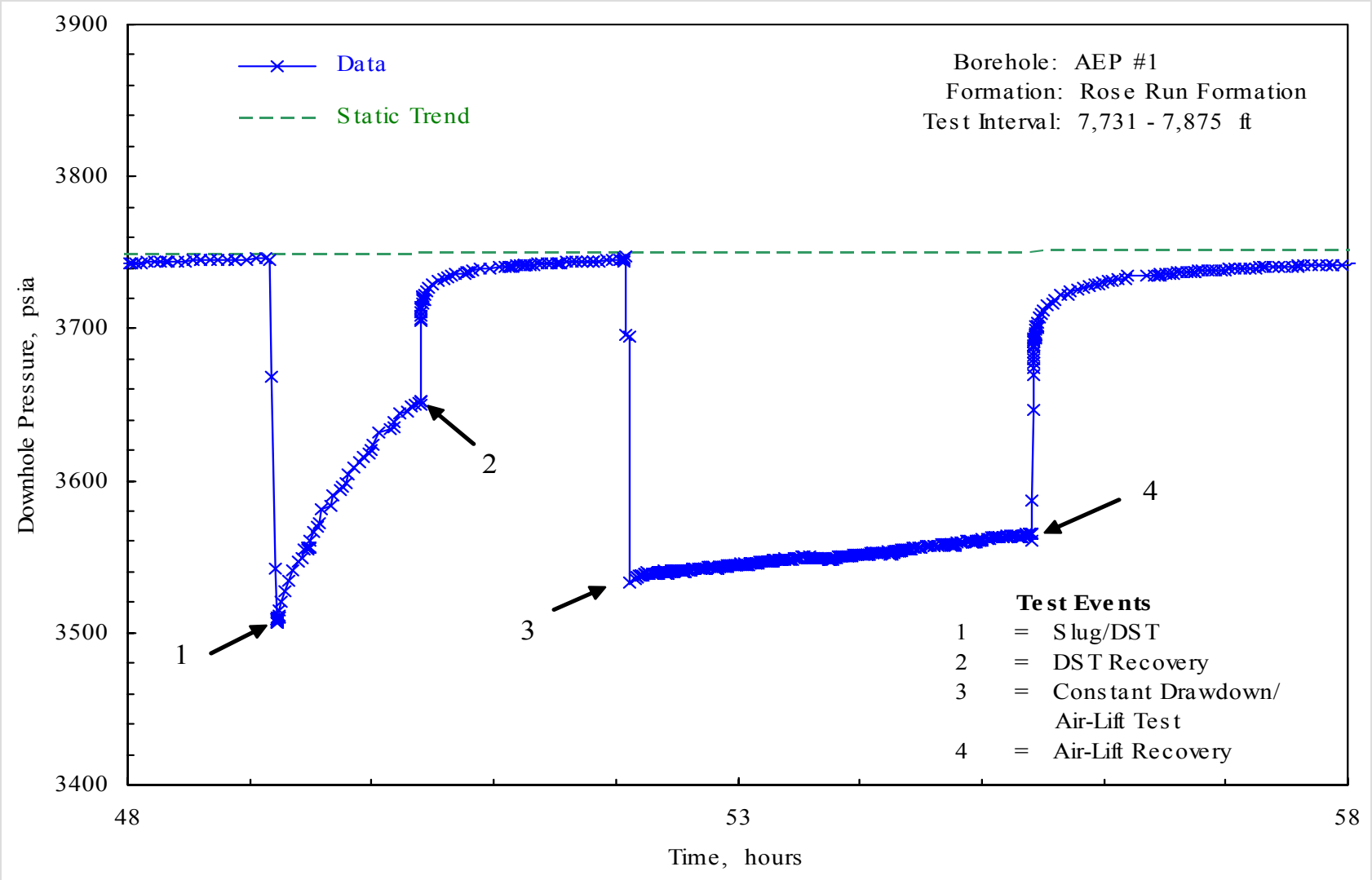
Reservoir: Detailed Hydraulic Characterization Methods

- General Characteristics
  - Test interval isolated using straddle-packer system
  - Multiple-test methods provide a range of investigation scale from small to large
  - Provides detailed quantitative information on reservoir permeability
  - Formation damage/well skin effects can be identified/quantified

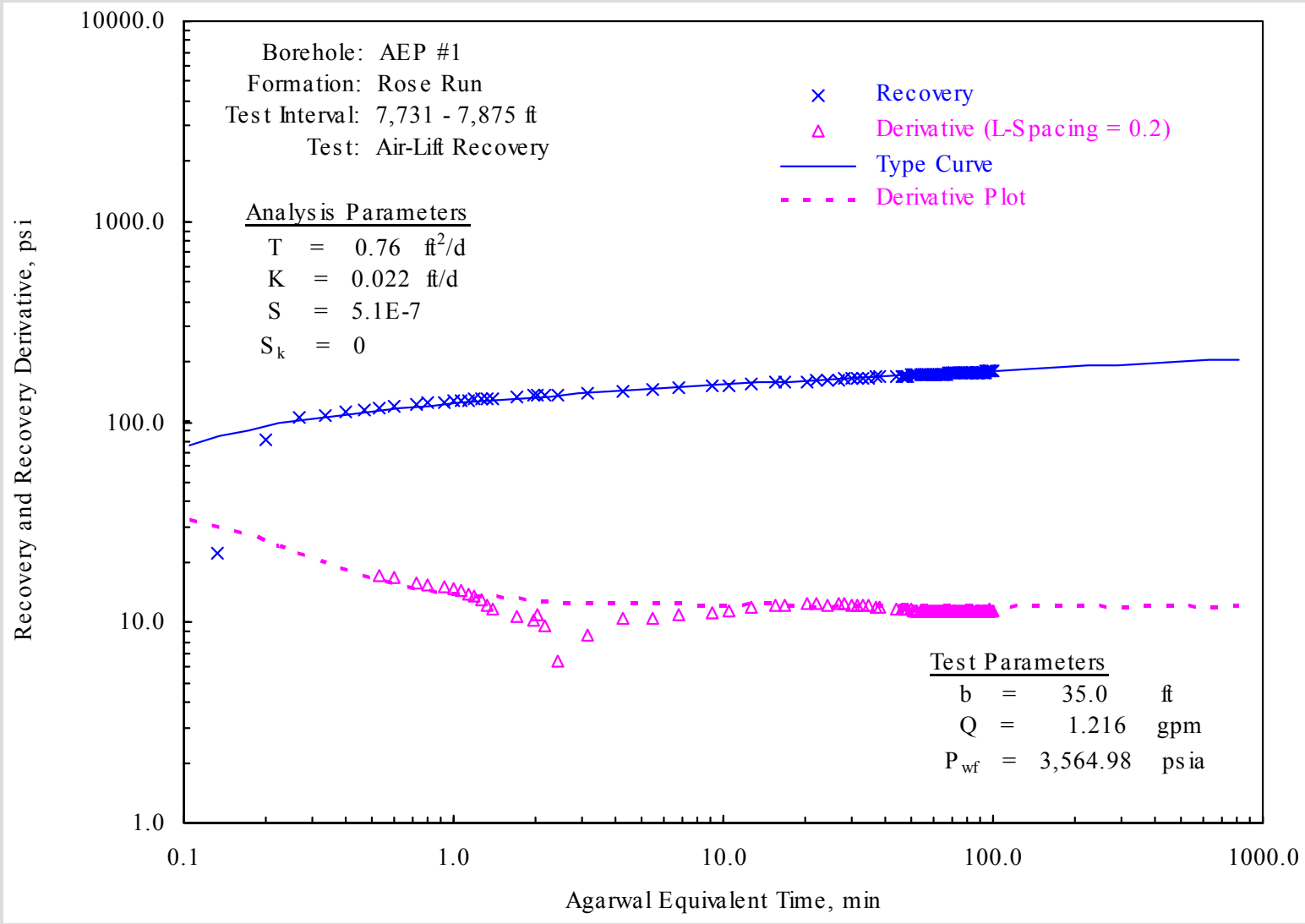
Detailed Hydraulic Test Methods Cont'.

- Characterization Test Methods
  - Slug/DST
  - Constant-Drawdown/Rate Tests
    - Drawdown Phase Analysis
    - Recovery Phase Analysis
  - Test History Match
  - Laboratory Core Permeability

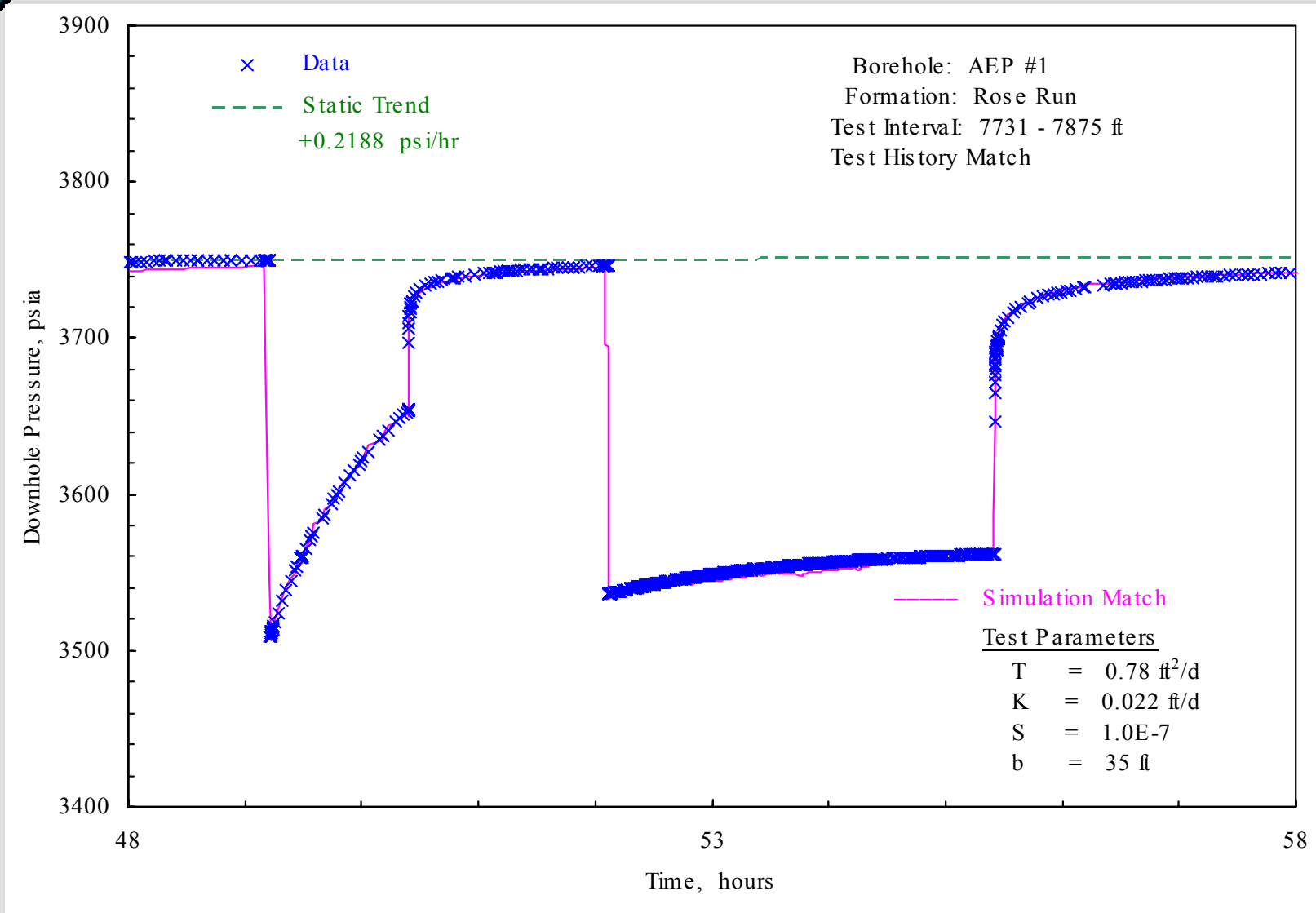
Detailed Characterization: Rose Run



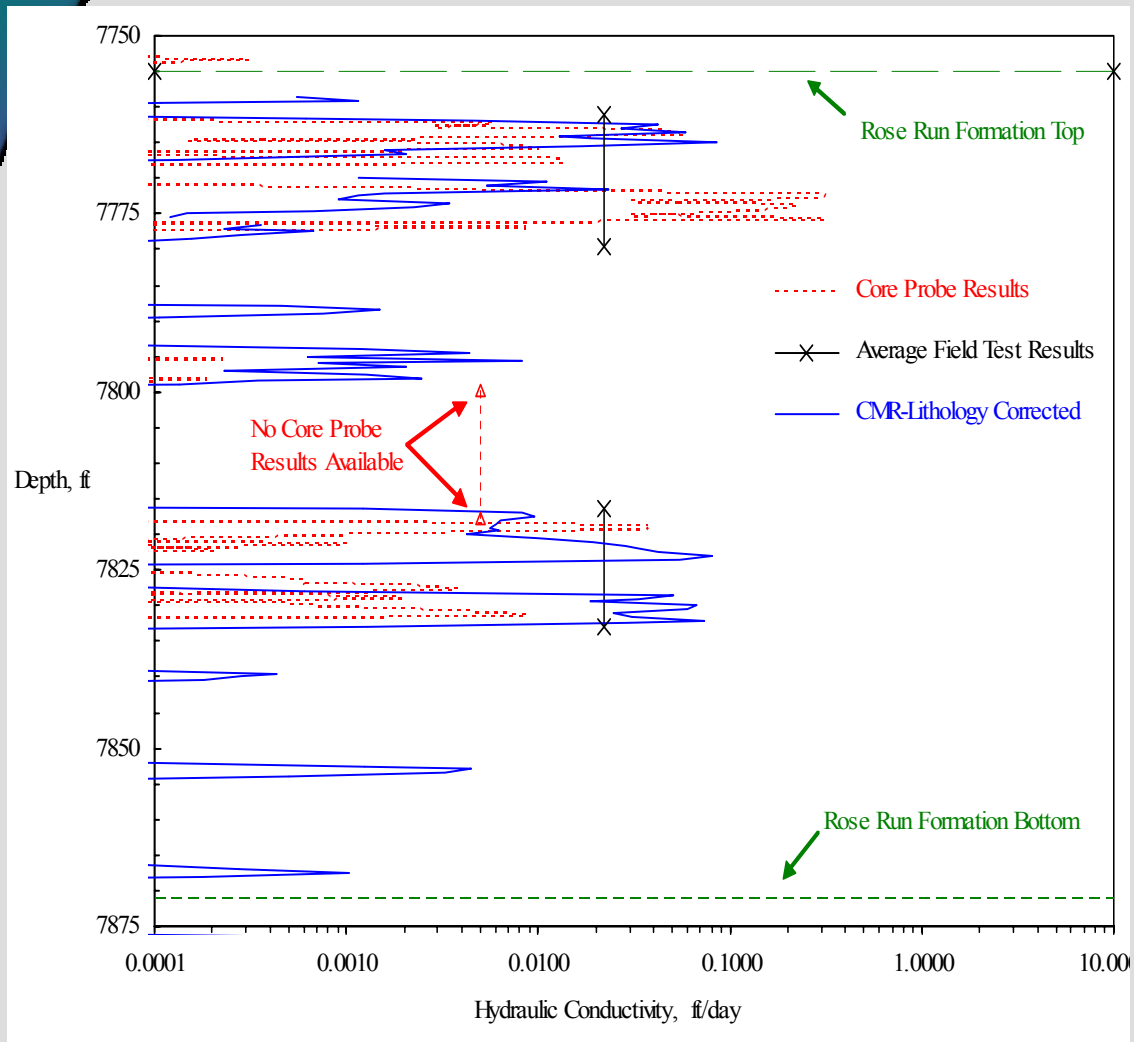
Detailed Characterization: Air-Lift Recovery Test Analysis



Detailed Characterization: Test History Match



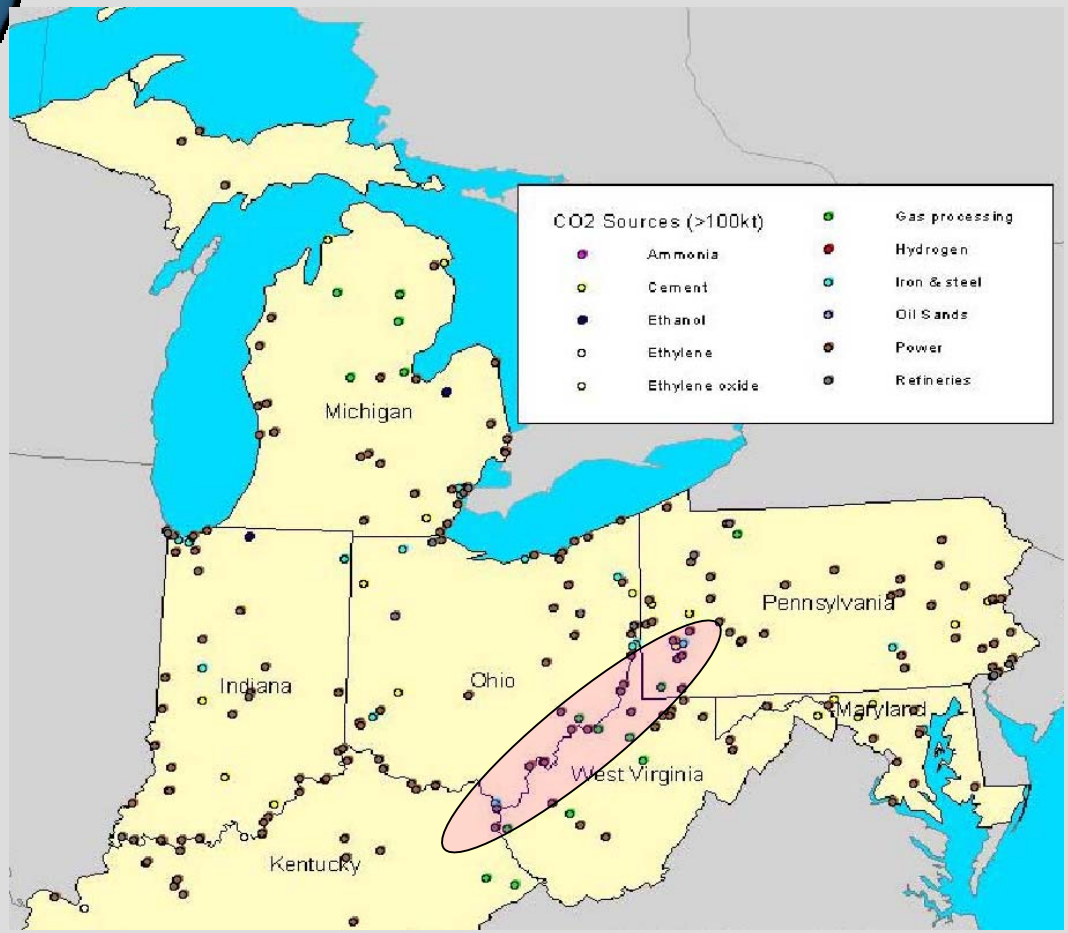
Comparison of Rose Run Core Profile K Scan, CMR, and Detailed Hydraulic Test Results



General Findings:

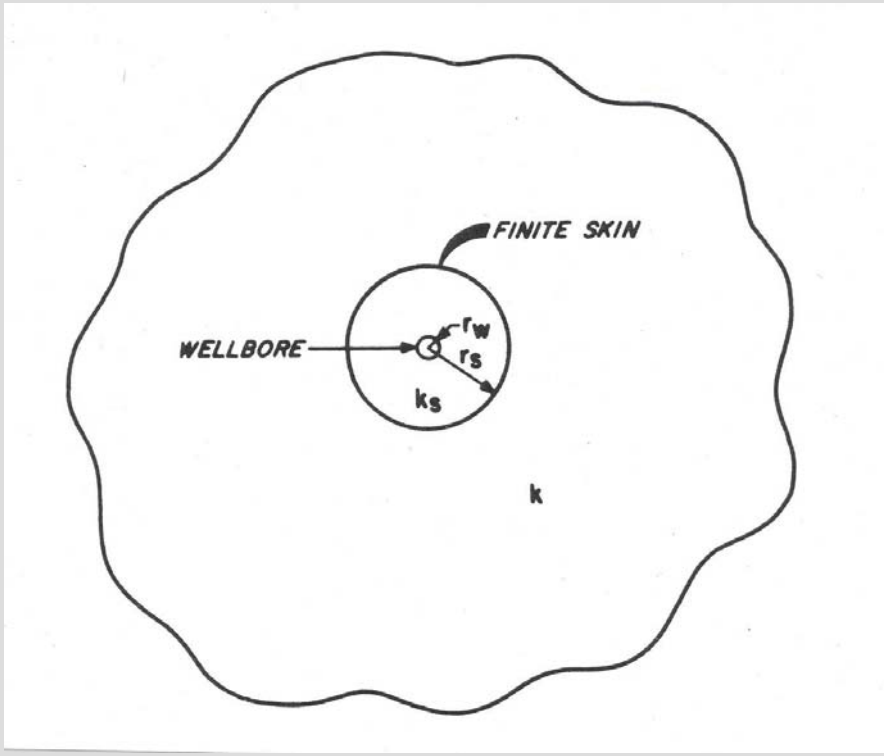
- Relatively close correspondence between converted core and CMR permeability results
- Correspondence between detailed hydraulic test results lends credence to the continuous vertical distribution depicted by the core probe scan and CMR survey

Regional Occurrence of Permeability Zone Within Copper Ridge



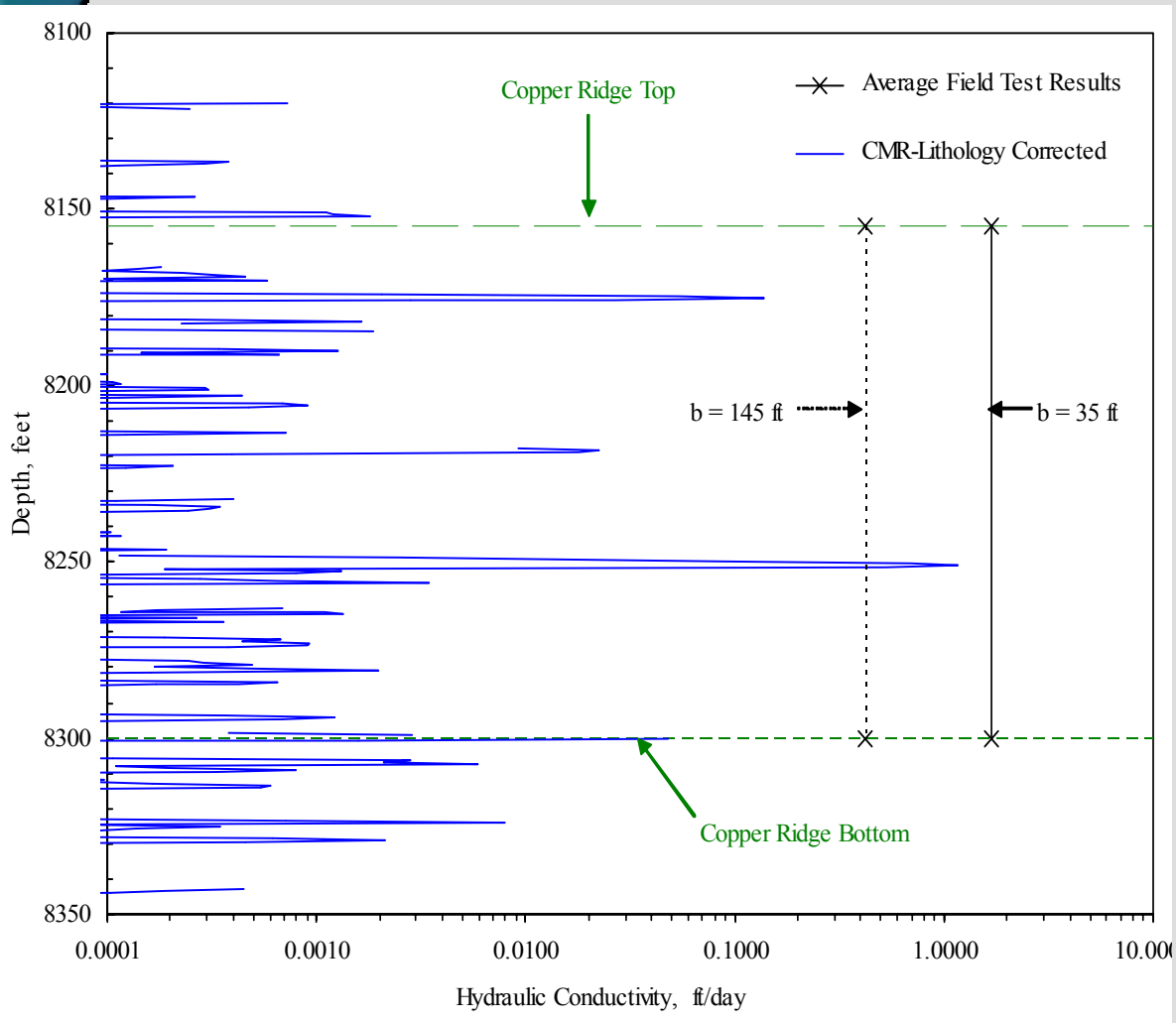
- Open borehole fluid dynamics logging suggested significant inflow production zones occurring from the Copper Ridge Dolomite
- Permeable “B” Zone within the Copper Ridge appears to occur over a limited 4-state region

Permeability Characteristics Within Copper Ridge Dolomite



- Wireline surveys suggest the presence of multiple thin dissolution layers, which may represent zones of significant permeability/ porosity within the formation
- Detailed hydraulic testing indicates moderate formation damage/well skin (+48)
- $S_k = \ln(r_{sk}/r_w) \times (k/k_{sk} - 1)$

Comparison of Copper Ridge CMR and Detailed Hydraulic Test Results



- Formation damage is likely variable within the formation
- Less correspondence between CMR and average detailed hydraulic test results
- CMR may not provide a complete permeability distribution within the formation

Summary

- Use of reconnaissance-level and detailed hydraulic characterization methods have been instrumental in identifying two candidate reservoir zones for carbon injection/sequestration at AEP #1
  - Rose Run Sandstone
  - Copper Ridge Dolomite
- Hydraulic property results obtained using these methods are consistent with reported regional values and observations for these two characterized reservoir zones

Summary

- Reconnaissance-level hydraulic characterization methods provided representative vertical distributions of permeability for open borehole sections and within reservoir zones not significantly impacted by formation damage/well skin effects

- For reservoirs exhibiting formation damage, care should be exercised in using permeability distributions obtained with these methods