RESERVOIR QUALITY OF THE MESAVERDE GROUP UINTA AND PICEANCE BASINS UTAH AND COLORADO

How can rock typing and petrography help us to understand and predict reservoir performance?

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Analysis of Critical Permeability, Capillary Pressure and Electrical Properties for Mesaverde Tight Gas Sandstones from Western U.S. Basins

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Williams Production, Piceance Basin Team

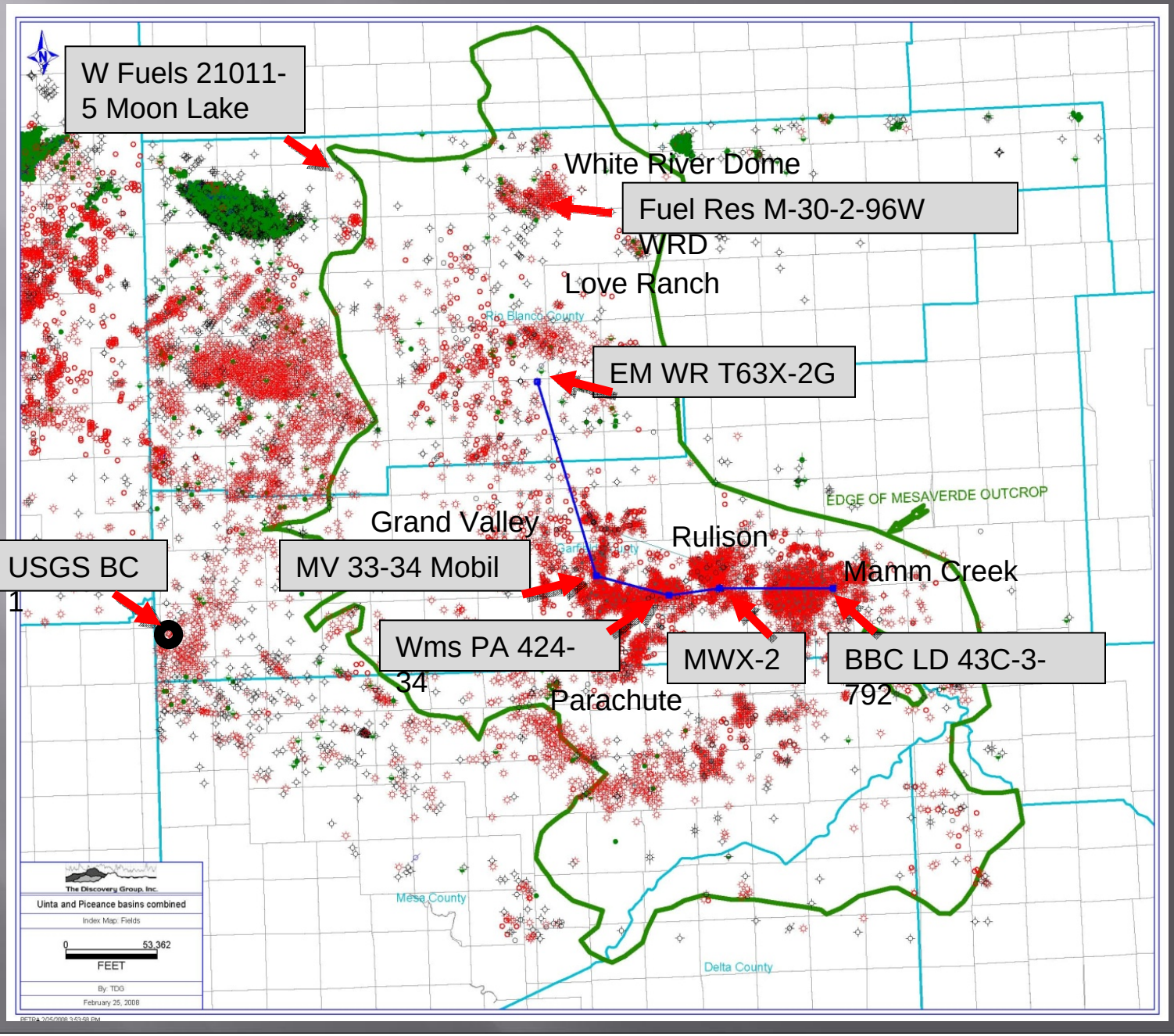
Outline

- Background and objectives
- Data set: core description, core plug sampling, KGS lab measurements, log data, legacy core data, thin section petrography
- Rock typing, digital rock types
- Influence of diagenesis on reservoir quality
- Reservoir quality issues (rock type & petrophysics)

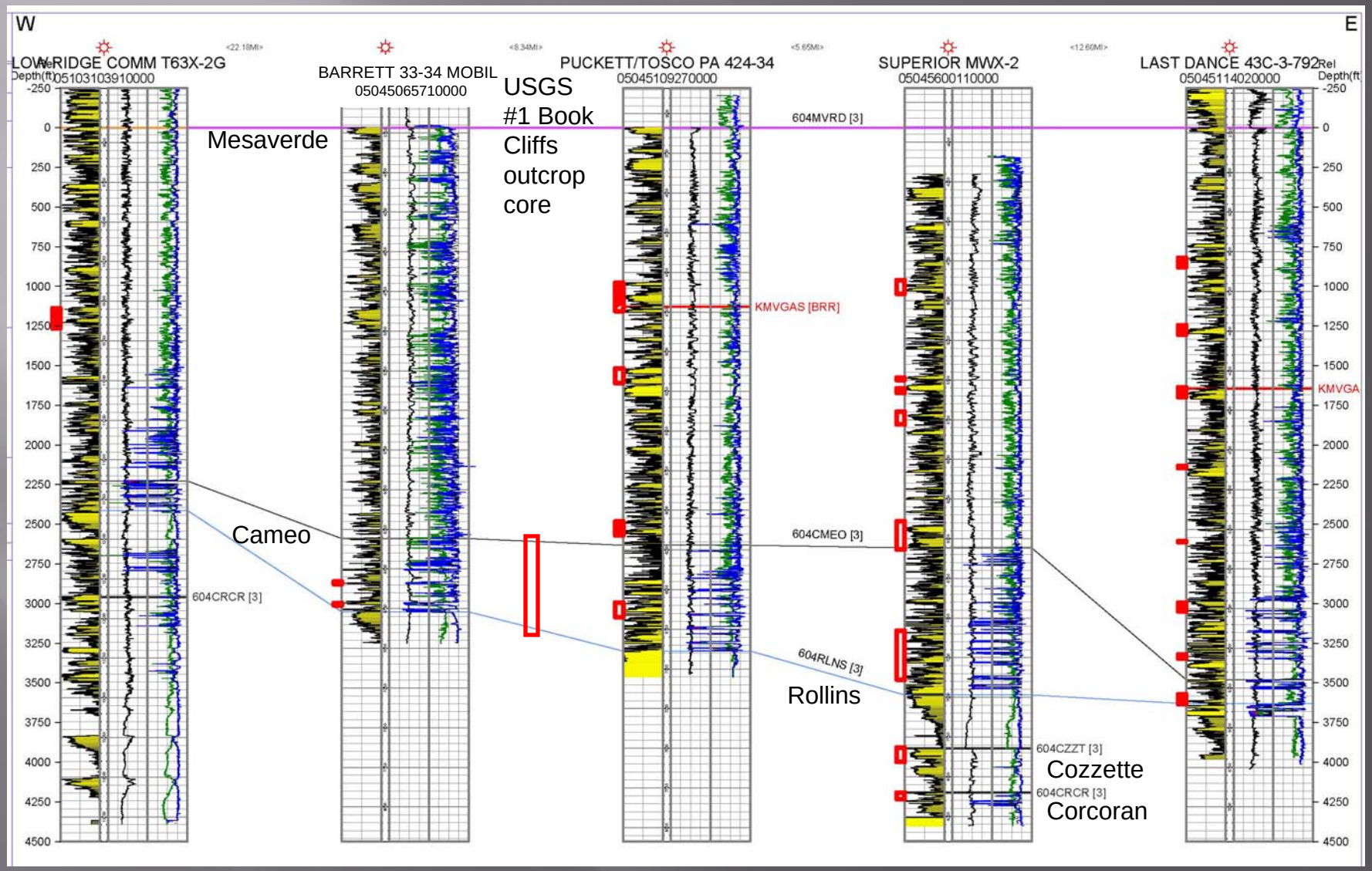
Data

- Routine core analysis:
  - Uinta basin - 539 samples, Piceance 629 samples
- Mercury invasion and imbibition curves for 8 samples
- Core description and petrography :
  - Uinta basin - 7 wells, 1 shallow bore hole, 2060' core, 26 thin section point counts
  - Piceance basin - 6 wells, 2 shallow bore holes, 1168' core, 46 thin section point counts
- Log analysis:
  - Modern log suites for 9 wells, various vintages and format for 7 older wells and shallow bore holes

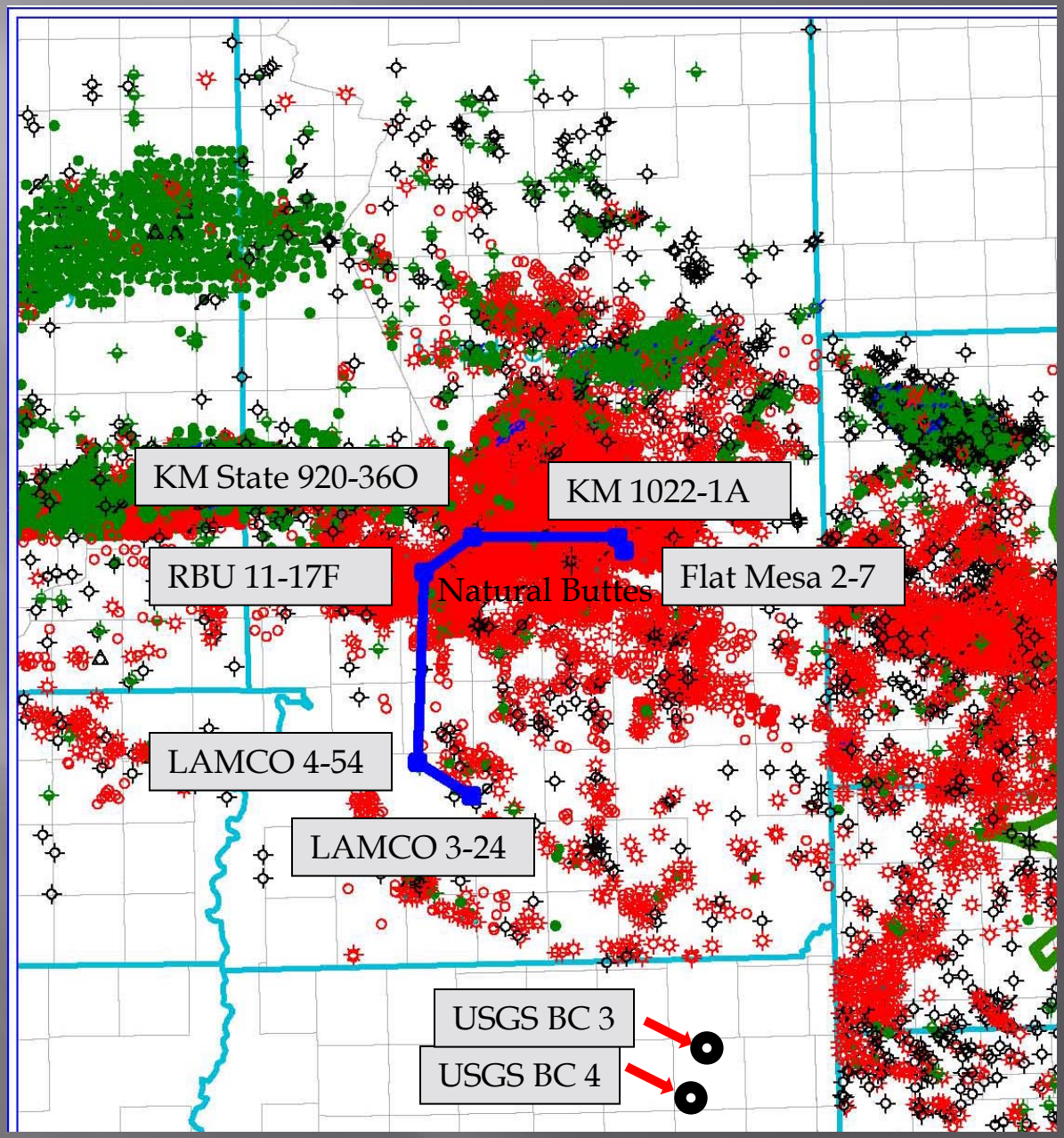
Sampling of Mesaverde Group - Piceance Basin



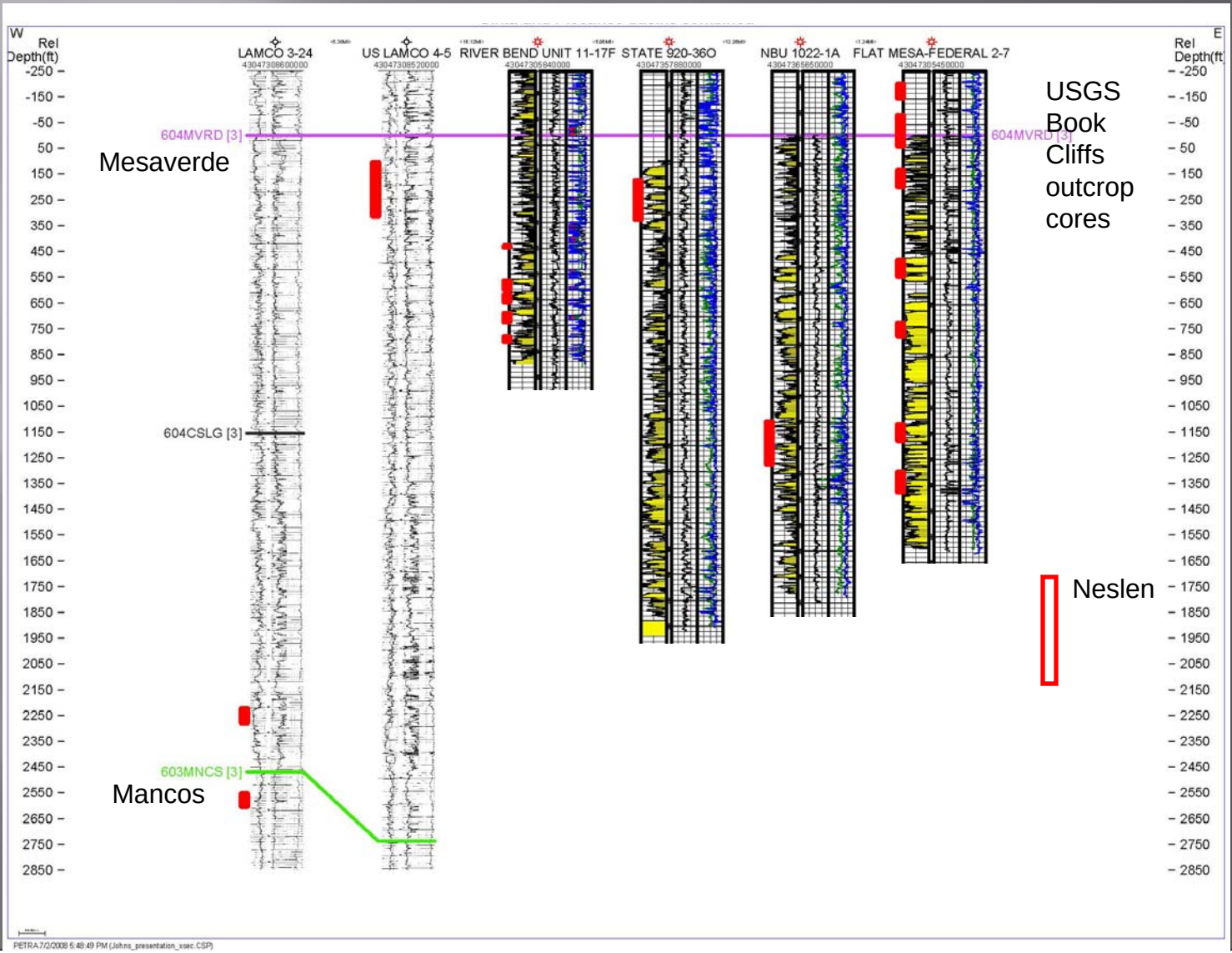
Stratigraphic distribution of cores Piceance Basin



Sampling of Mesaverde Group, Uinta Basin, Utah



Stratigraphic distribution of cores, Uinta Basin



Core Description and digital rock typing

- Standard core description format
  - lithology
  - grain size
  - sedimentary structures
  - bedding and contacts
- 5 digit system to characterize lithofacies
  - basic type (Ss, Ls, coal)
  - grain size/sorting/texture
  - porosity/consolidation
  - sedimentary structure
  - cement mineralogy

Five Digit Rock Typing System

Grain size/sorting	
10xxx	Shale
11xxx	Silty shale
12xxx	V shaly sandstone, siltstone
13xxx	Shaly sandstone
14xxx	VF sandsone
15xxx	F sandstone
16xxx	M sandstone
17xxx	C sandstone
18xxx	VC/Matrix supported cgl.
19xxx	Conglomerate
2xxxx	Limestone
30000	Coal
05000	Volcanic ash

Visible porosity	
xx0xx	0-2%, unfractured
xx1xx	0-2%, fractured
xx2xx	3-10%, unfrac'd
xx3xx	3-10%, frac'd
xx4xx	3-10%, abun fracs
xx5xx	>10%, unfrac'd
xx6xx	>10%, frac'd
xx7xx	>10%, unfrac'd
xx8xx	High, weak cons.
xx9xx	Unconsolodated

Sedimentary struc's	
xxx0x	Vert. dike
xxx1x	Bioturbated
xxx2x	Contorted
xxx3x	Discontin. lams.
xxx4x	Contin. lams.
xxx5x	Flaser bedded
xxx6x	Ripple laminated
xxx7x	Trough, planar tabular crossbeds
xxx8x	Planar laminated
xxx9x	Massive

Digital Rock Typing, cont.

Cement

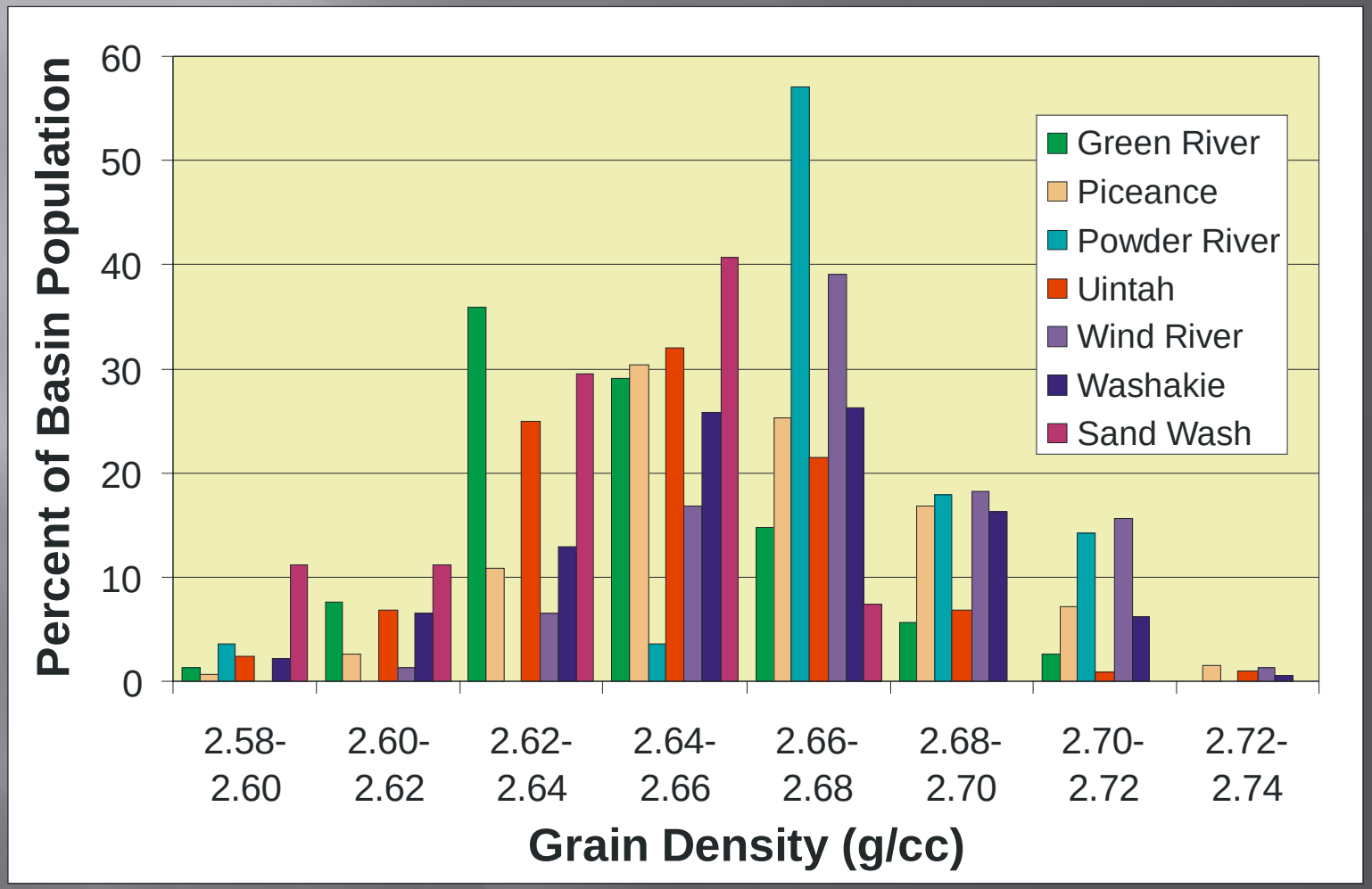
XXXX0	Pyrite
XXXX1	Siderite
XXXX2	Phosphate
XXXX3	Anhydrite
XXXX4	Dolomite
XXXX5	Calcite
XXXX6	Quartz
XXXX7	Authigenic clay
XXXX8	Carbonaceous
XXXX9	No pore filling

15277 - Medium sandstone with moderate porosity, unfractured, trough cross bedded, clay cemented

Utility of digital rock typing

- Excellent match with GR log traces
- Precise depth shifting of core analysis data
- Track statistical distribution of lithofacies, sampling and core analysis data
- Provides quantitative variables for multivariate analysis

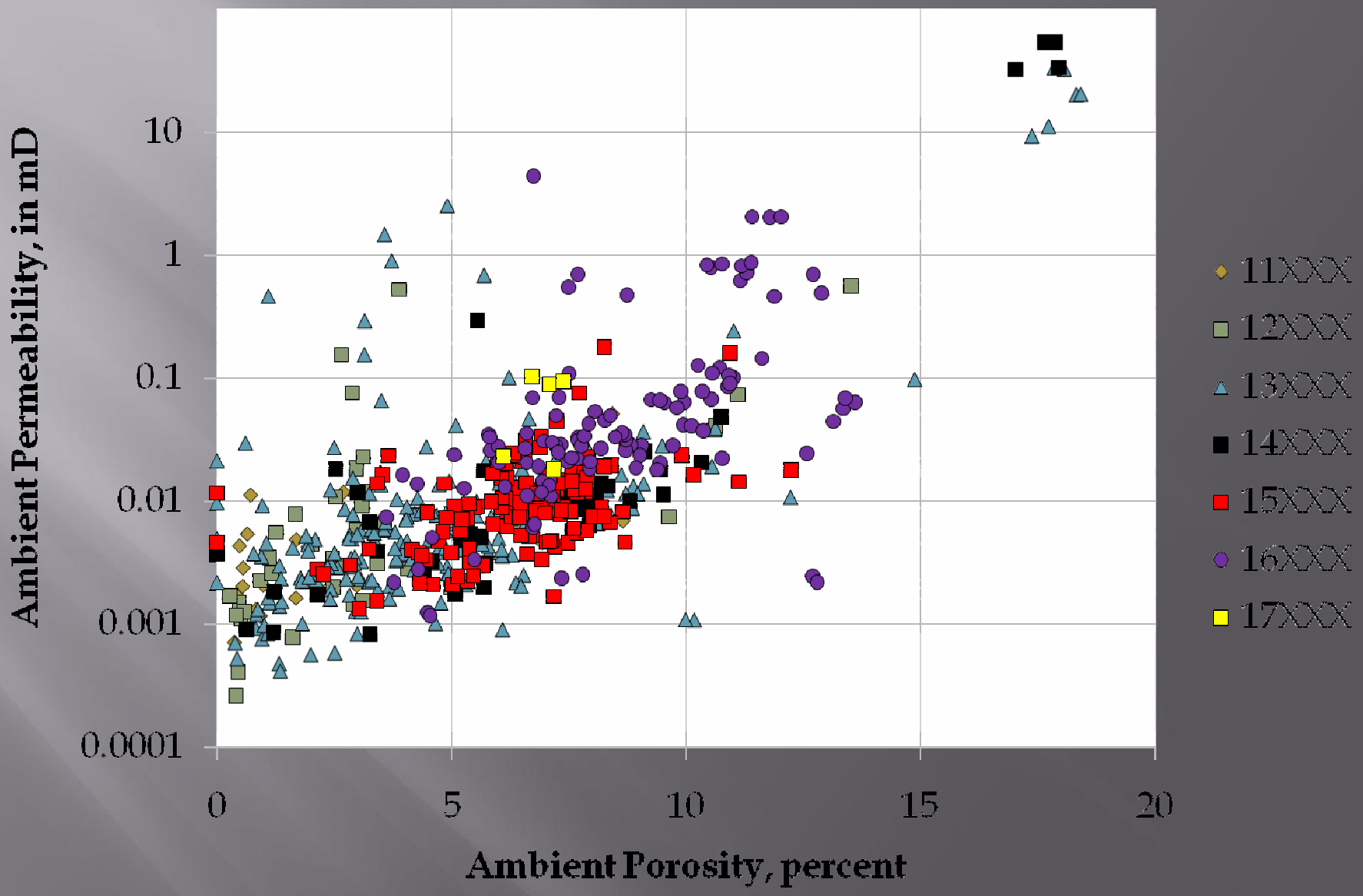
Grain densities of the Mesaverde Group



Utility of digital rock typing, continued

- Differences in detrital composition of sediment, depositional environment , burial history and diagenesis among basins requires separation of basins for assessment of reservoir quality
- Rock types are not restricted to a specific depositional environment

Phi/K Crossplot Mesaverde, Piceance Basin



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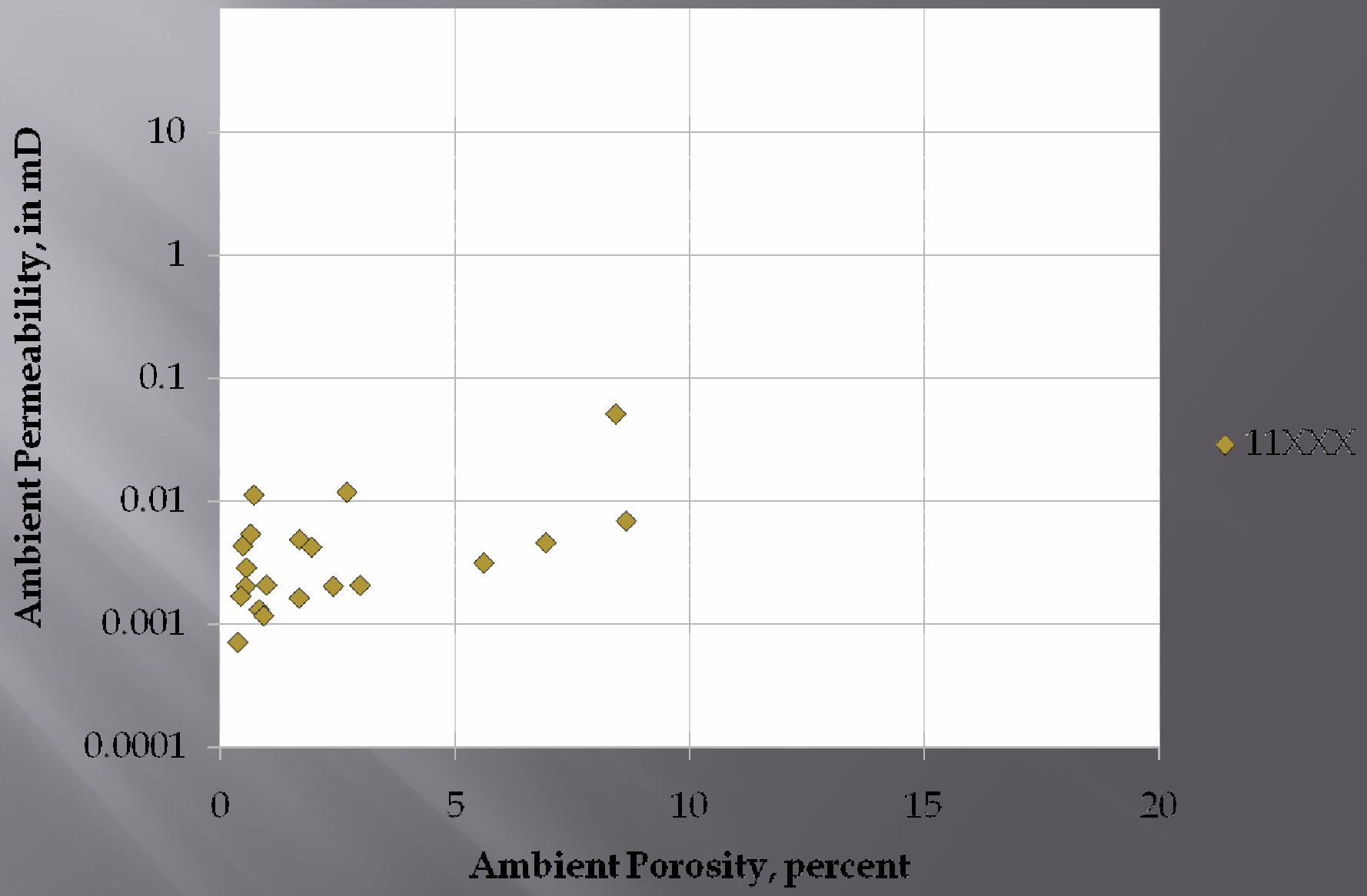
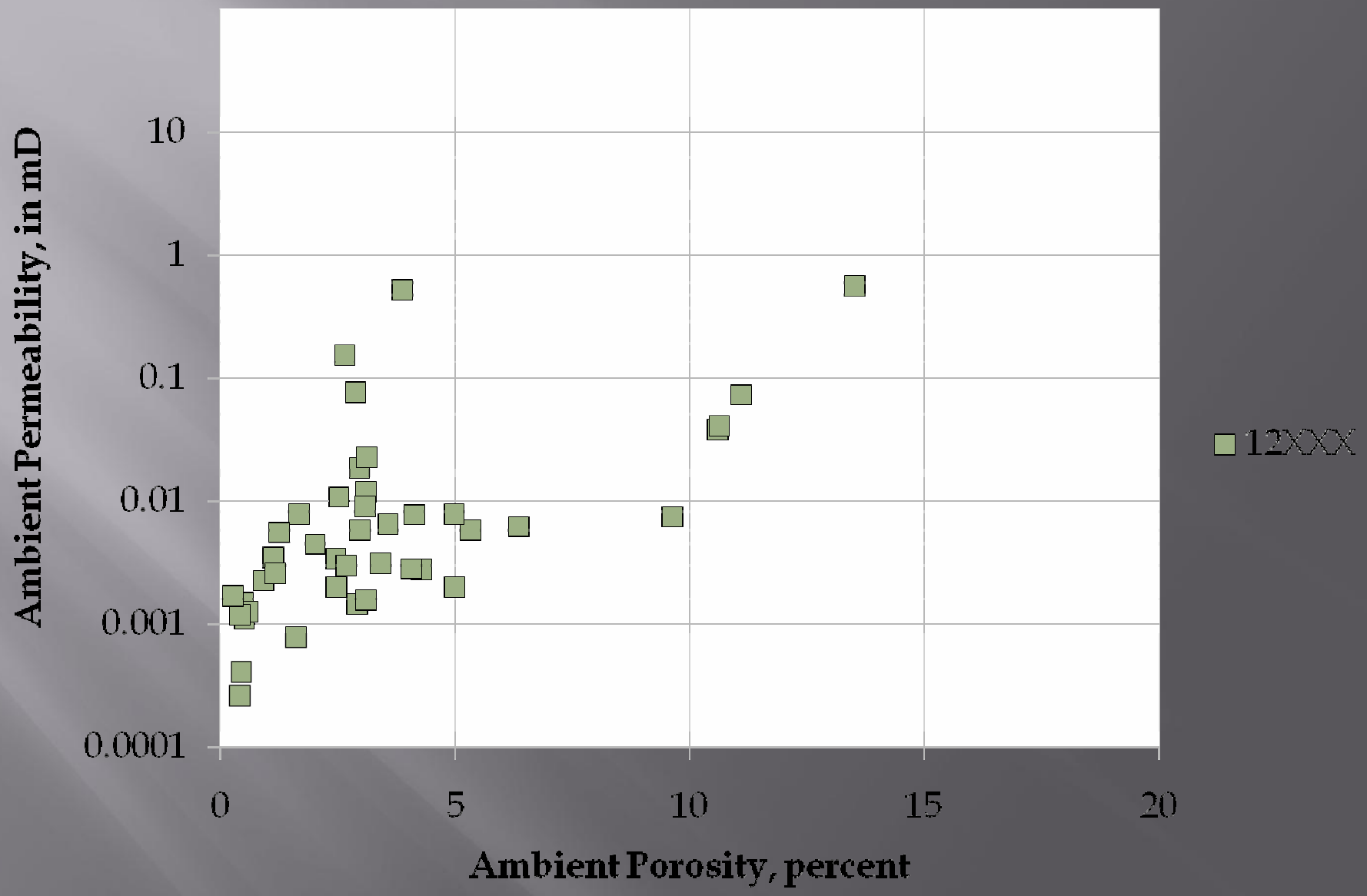
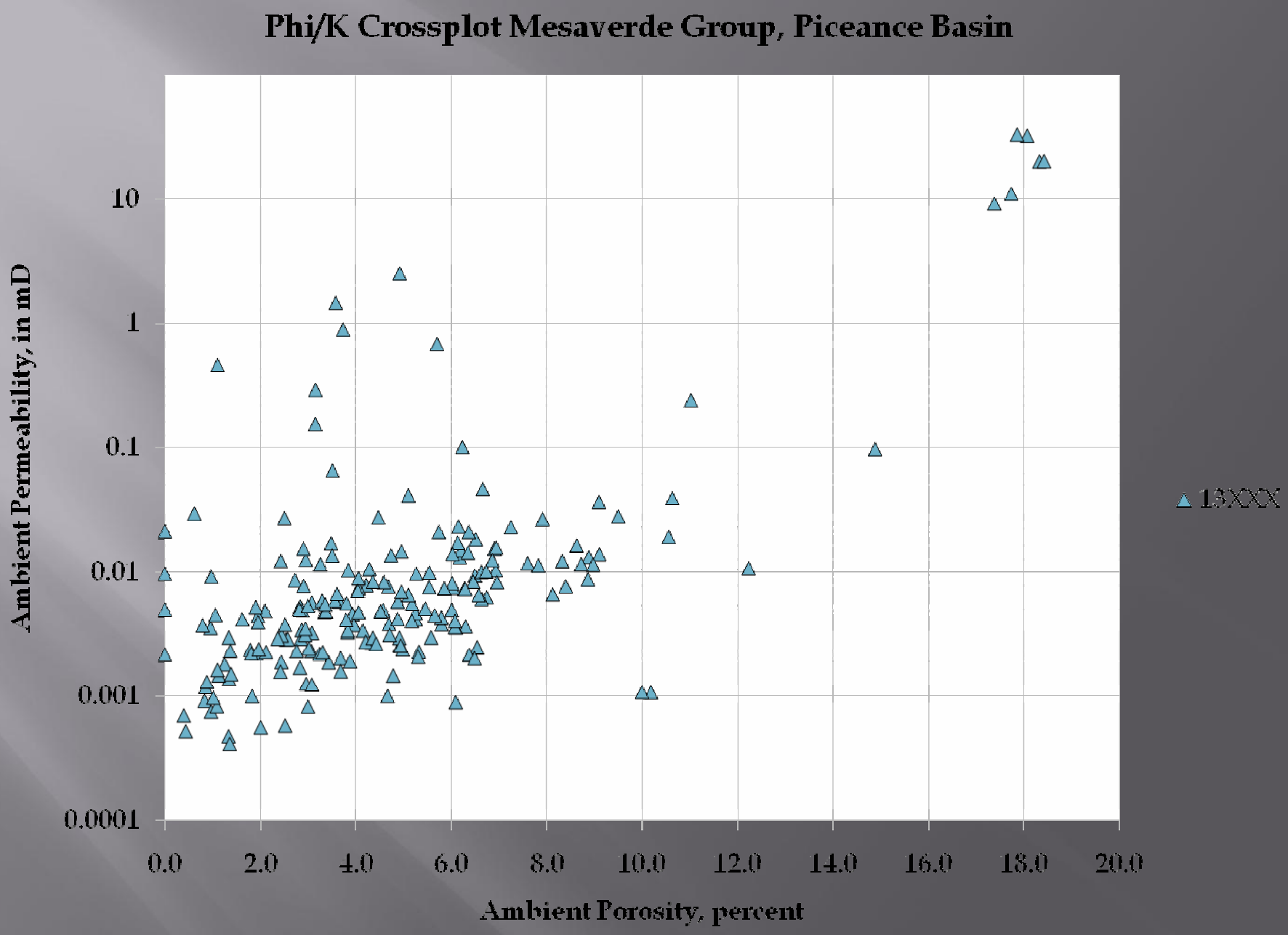
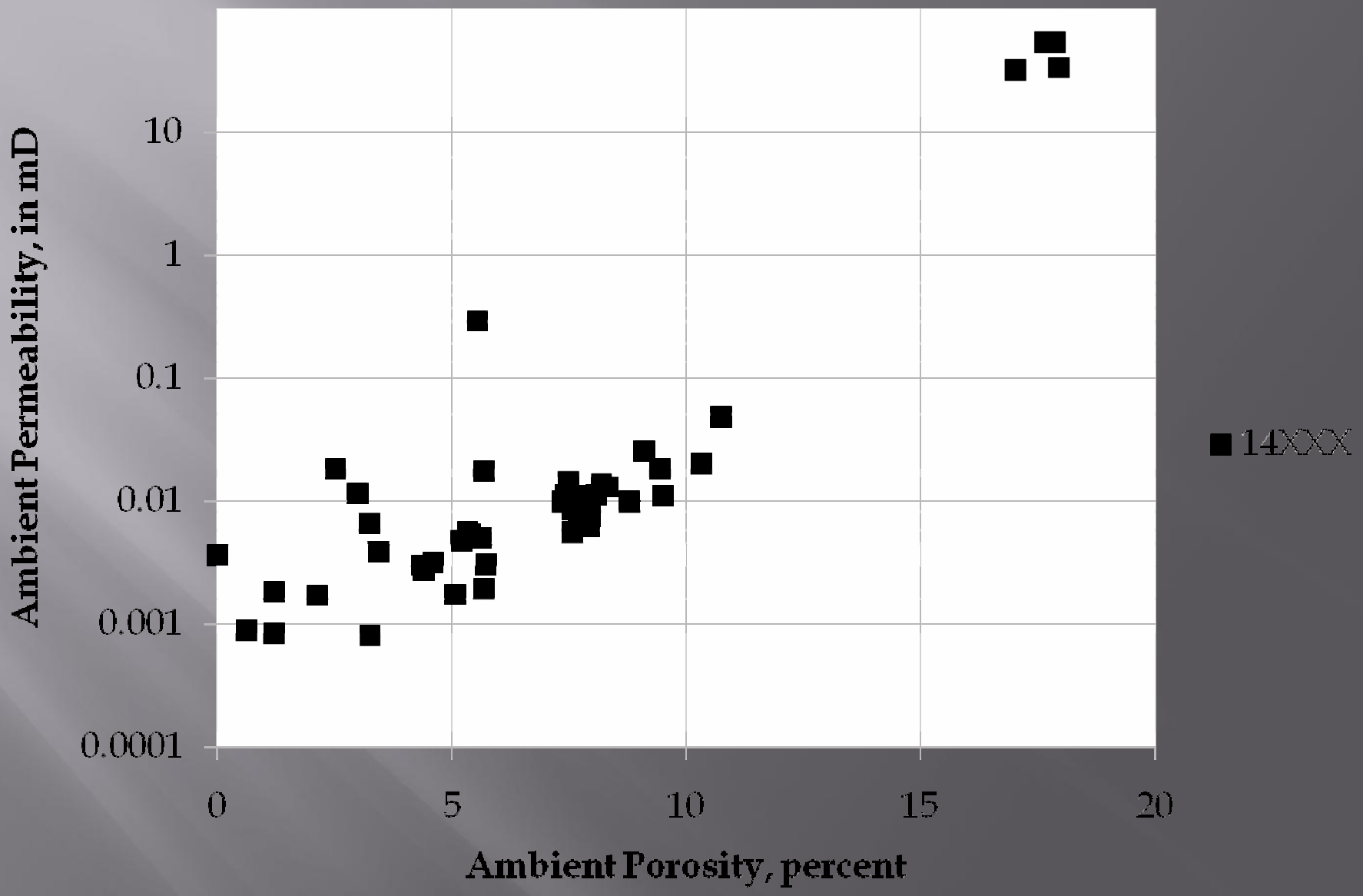


Phi/K Crossplot Mesaverde, Piceance Basin




Phi/K Crossplot Mesaverde Group, Piceance Basin
Ambient Permeability, in mD
10
1
0.1
0.01
0.001
0.0001
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Ambient Porosity, percent
13XXX

Phi/K Crossplot Mesaverde, Piceance Basin



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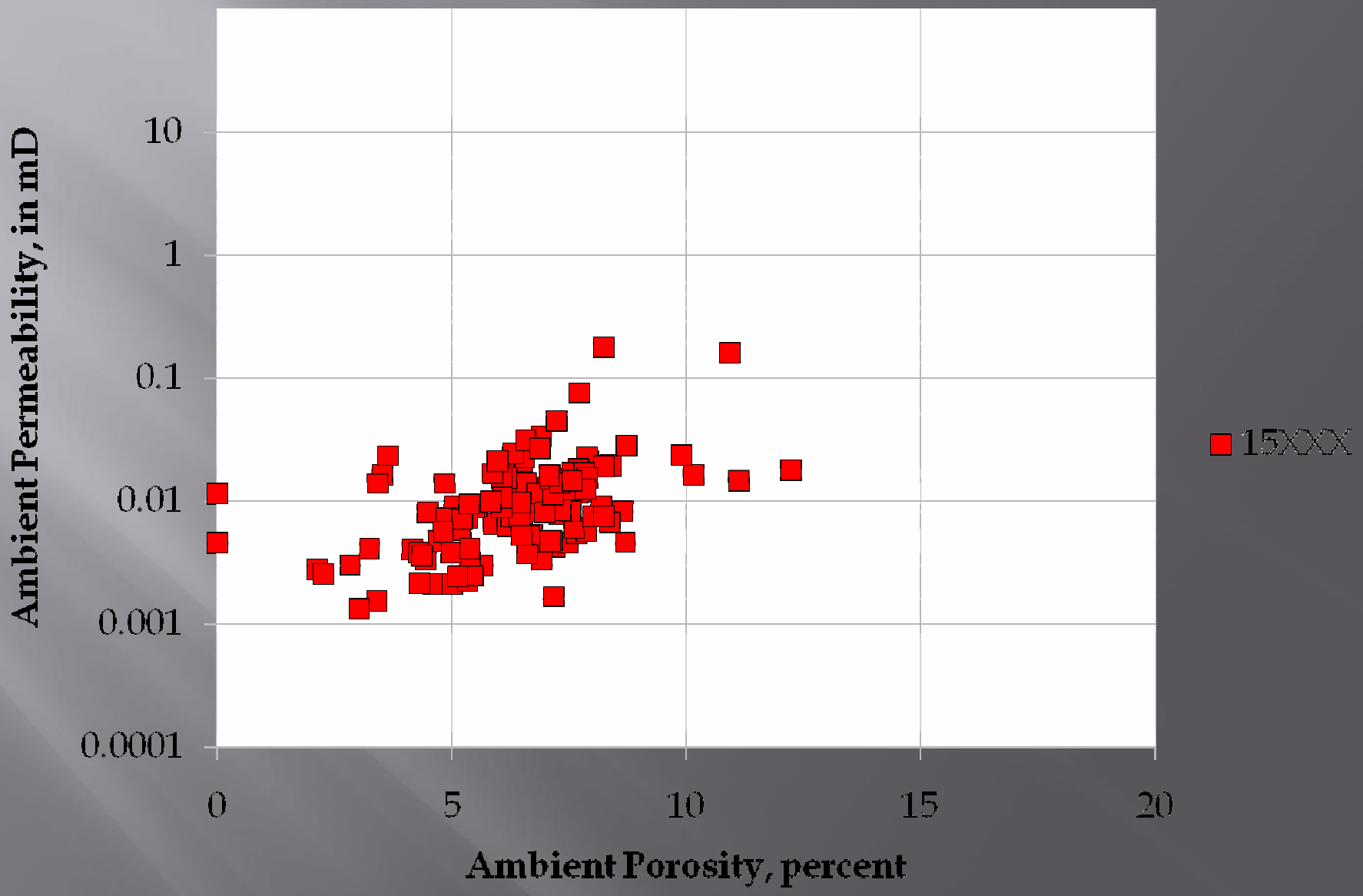

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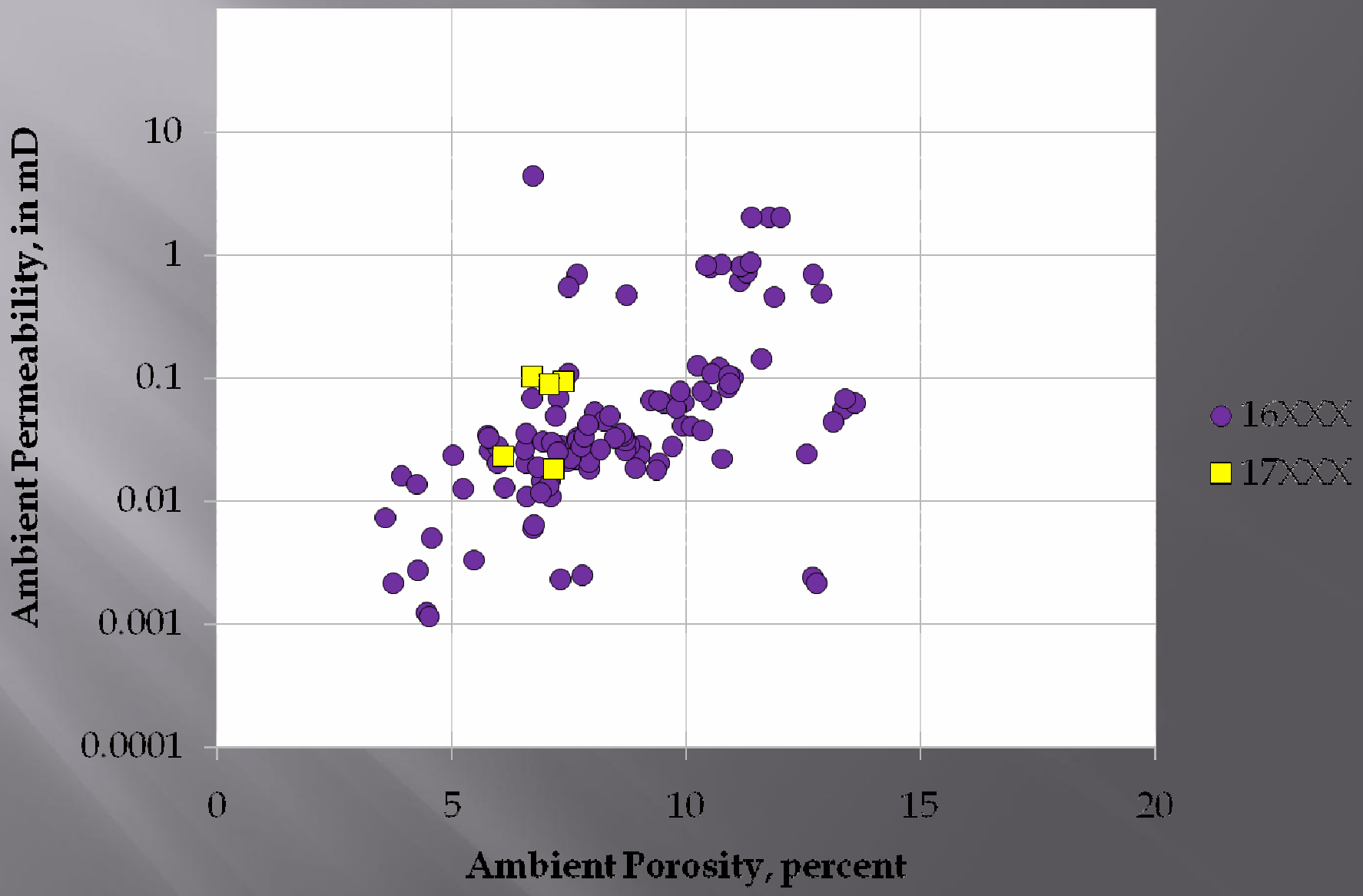


Porosity Distribution in the Mesaverde Group

Mesoporosity

Intergranular pores, primary and secondary

Moldic pores (partly and completely dissolved feldspars, carbonate and volcanic rock fragments)

Microporosity

Pore-lining and pore-filling clay cement

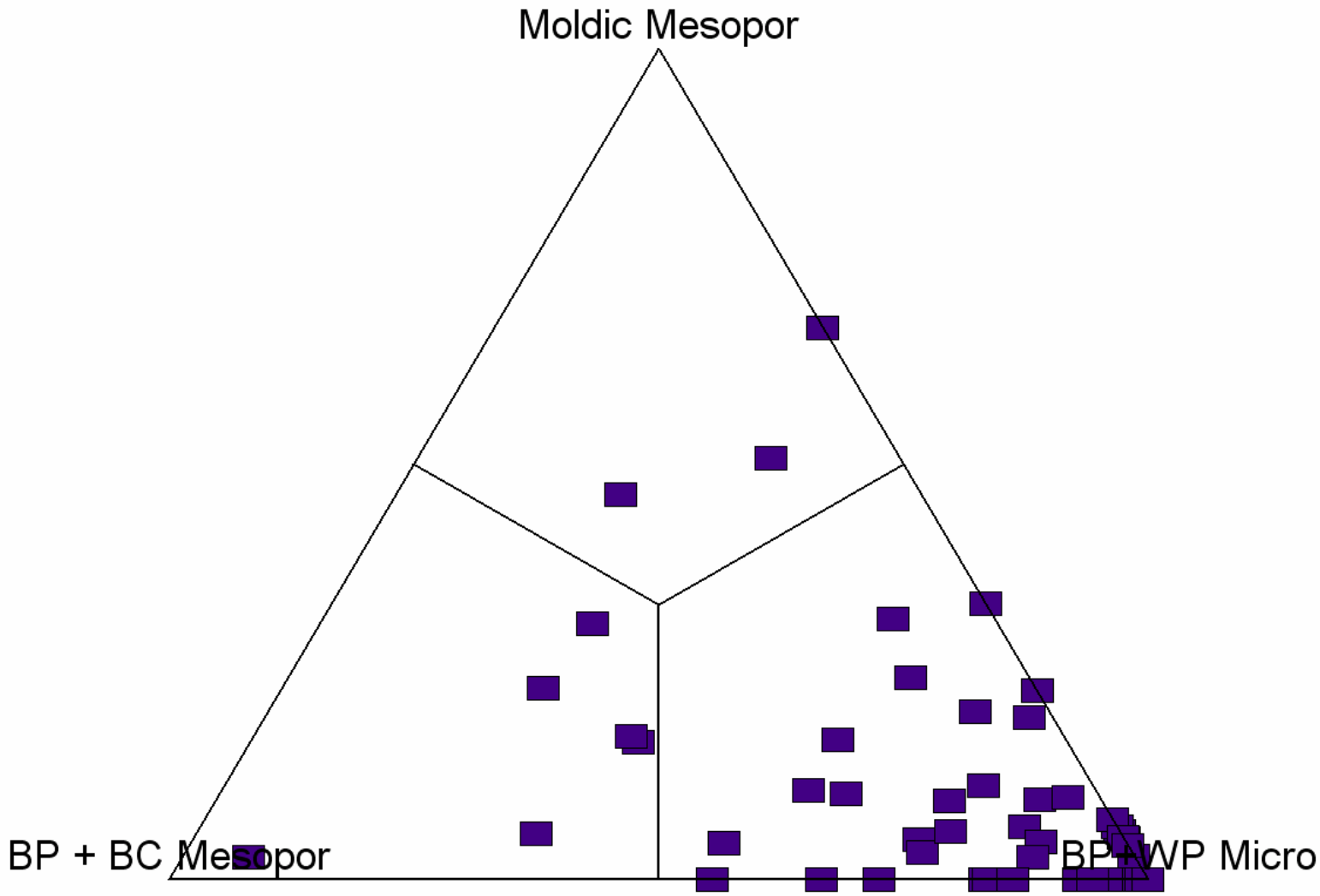
Intragranular micropores (altered VRF, clay pellets, shale rock fragments, clay and carbonaceous matrix)

Fractures

Macroscopic and microscopic (primarily crushed feldspars or chert, separations at quartz overgrowth boundaries)

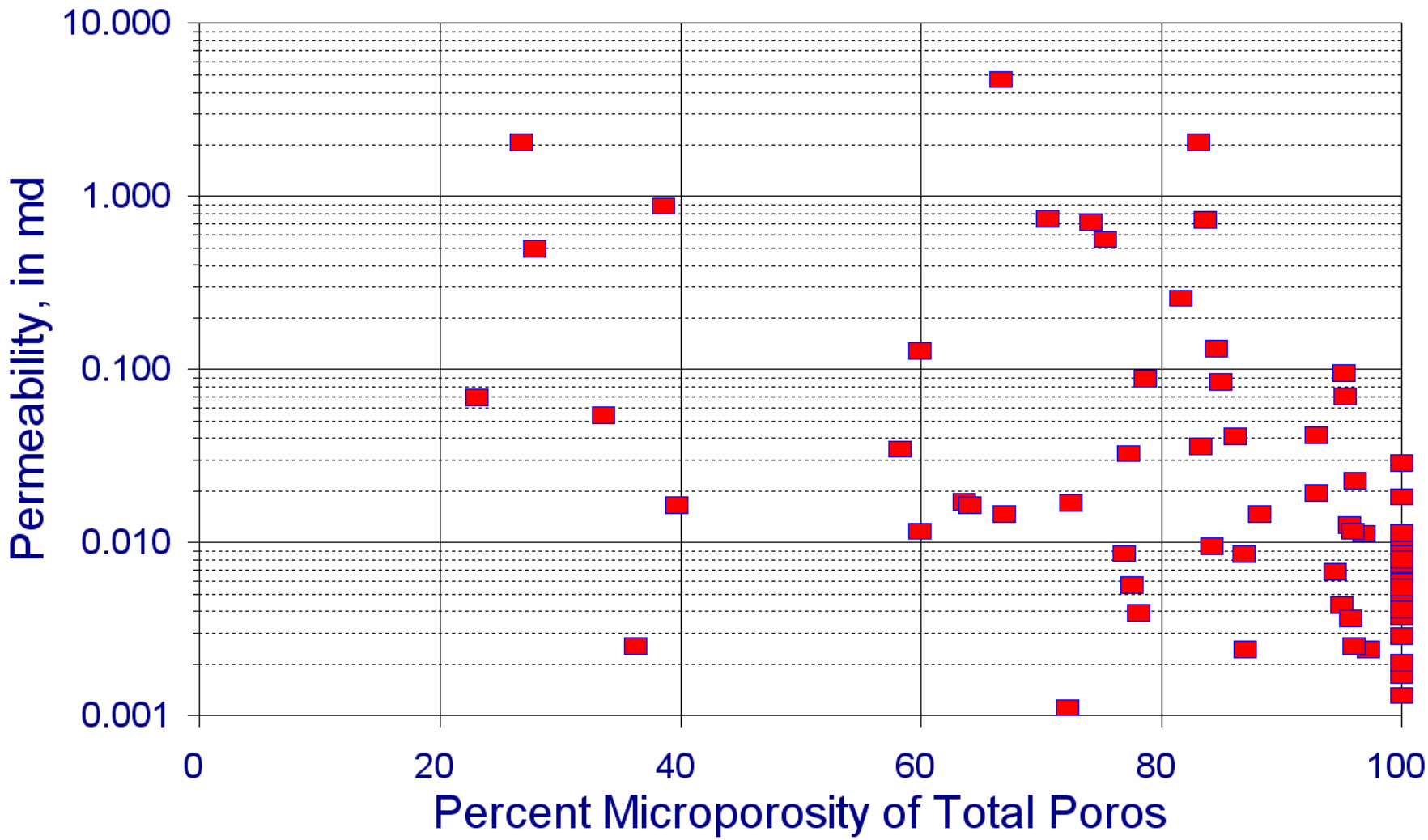
Porosity Distribution

Mesaverde Uinta and Piceance



Mesaverde Group

Uinta and Piceance Basins



Porosity Distribution in the Mesaverde Group

Type I

Conventional porosity – Primary intergranular and modified intergranular (e.g. quartz overgrowth cement, secondary intergranular), no clay cement, Mesoporosity >> Microporosity, low Swi, Phi=high, K=high

Type II

Moldic– May include primary intergranular and secondary intergranular Trace to absent clay cement, Mesoporosity >> Microporosity,
Low to moderate Swi, elevated Snwr, Phi=high, K=moderate

Type III

Restricted intergranular– Clay-lined pores and pore throats, some moldic and clay-filled intergranular microporosity, moderate to common clay cement, Microporosity > Mesoporosity, Moderate to high Swi, elevated Snwr, Phi=moderate, K=low

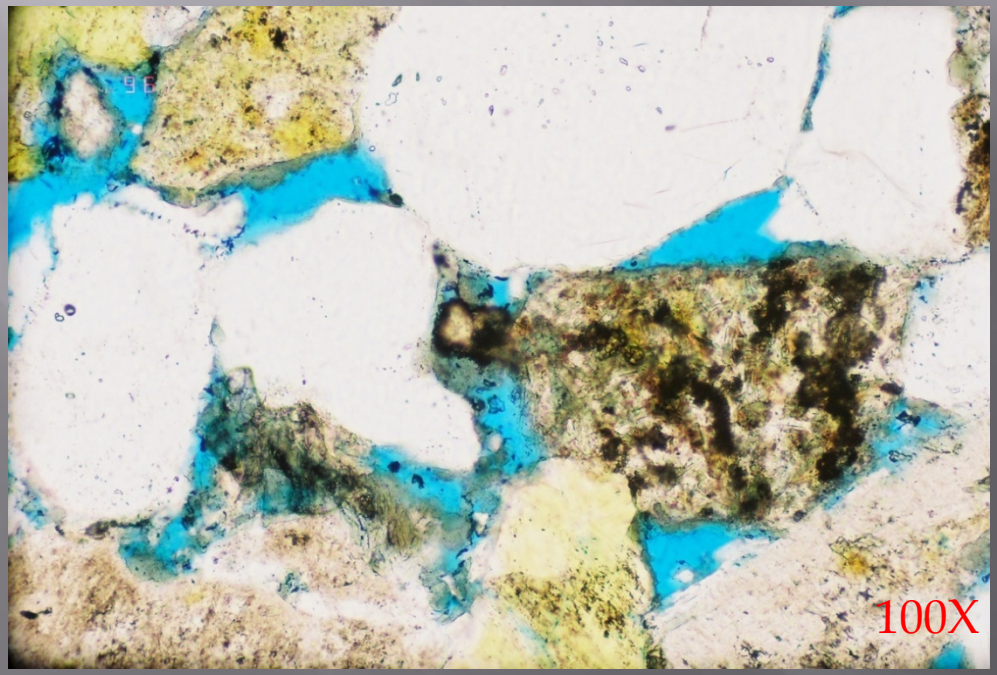
Porosity Distribution in the Mesaverde Group

Type IV

Microintergranular– Clay-filled intergranular pores, moderate to common clay cement, Microporosity >> Mesoporosity, High Swi,
High pore entry pressure, Phi=moderate to low, K=low to extremely low

Type V

Nanointergranular– Typical of mudstones, clay-sized intergranular, common clay or carbonaceous material,
Microporosity only, high Swi, extremely high pore entry pressure,
Phi=moderate to low, K=low to extremely low



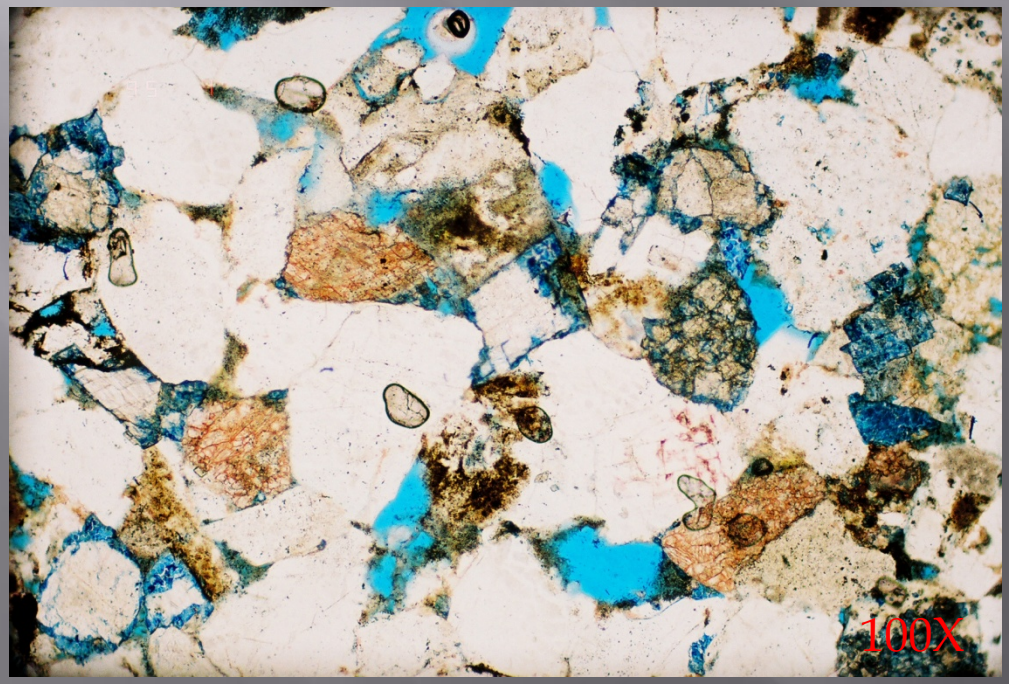
Type I (moderate compaction)

Porosity consists of moderately connected primary and secondary intergranular mesopores and traces of pore-lining chlorite clay containing microporosity.

Quartz cement and ferroan calcite are sparse.

Lack of pore-lining clay cement reduces Swi and improves relative permeability.

Barrett Last Dance 43C, 3544.9′
Rock type 16277
11.4% 2.65 g/cc Ka=0.8716 mD



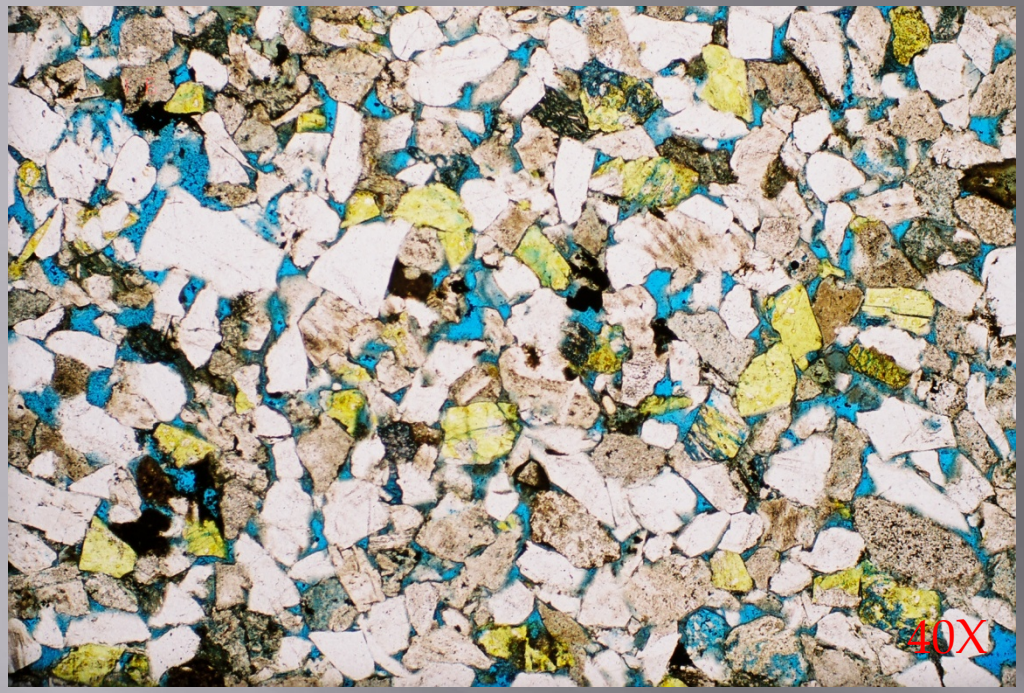
Type II

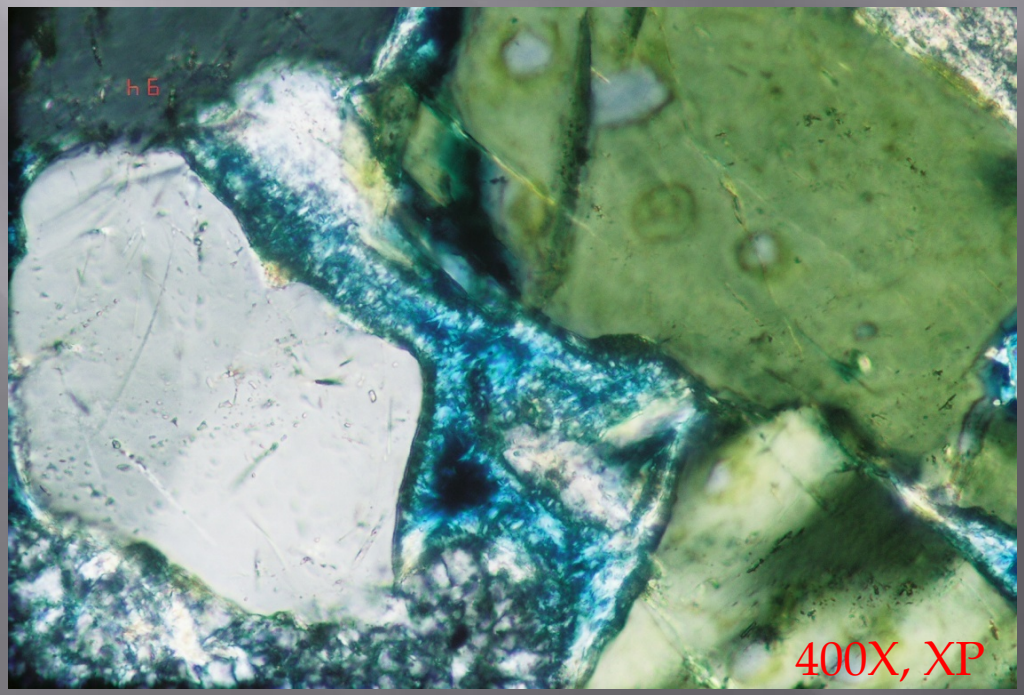
Porosity consists of poorly to moderately connected moldic and secondary intergranular mesopores with traces of pore-lining ML/IS(?) clay containing microporosity.

Quartz cement is prominent, ferroan calcite is sparse.

Pore-lining clay cement causes elevated Swi and reduced relative permeability.

Williams PA 424, 6148.8’ 15276
9.9% 2.66 g/cc Ka=0.0237 mD



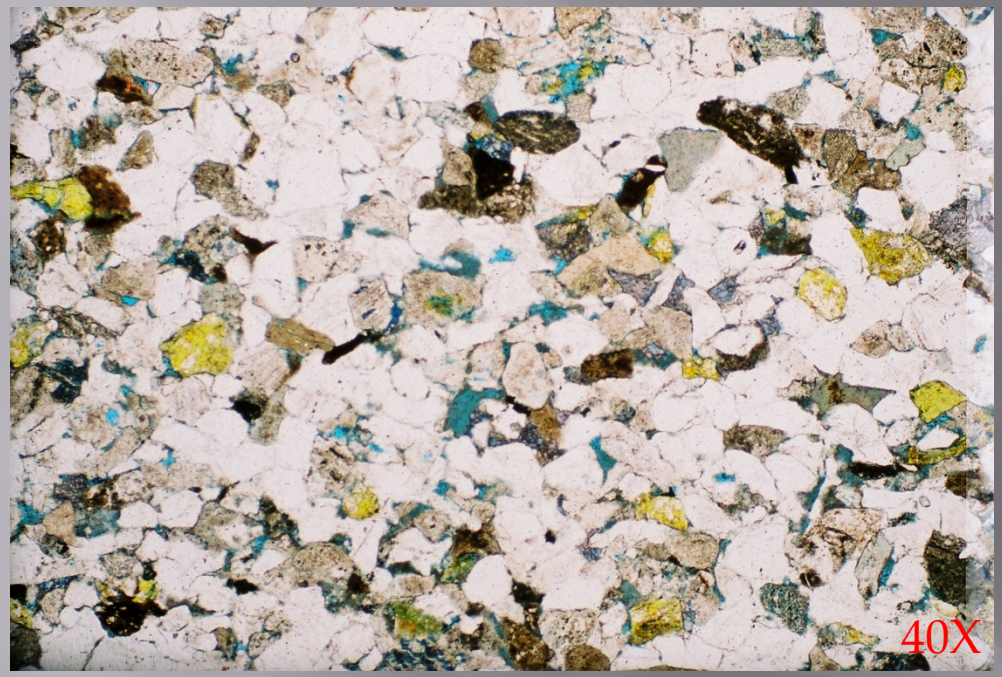


Type III

Porosity consists of clay-lined intergranular pores, pore throats are occluded by clay cement, which causes elevated Swi and reduced relative permeability.

Inhomogeneous packing and over-sized intergranular pores indicate the development of secondary intergranular porosity.

Williams PA 424, 4600.3’ 15297
12.2% 2.65 g/cc Ka=0.0178 mD



Type IV

Porosity consists almost entirely of sparse, poorly connected, clay-filled intergranular microporosity.

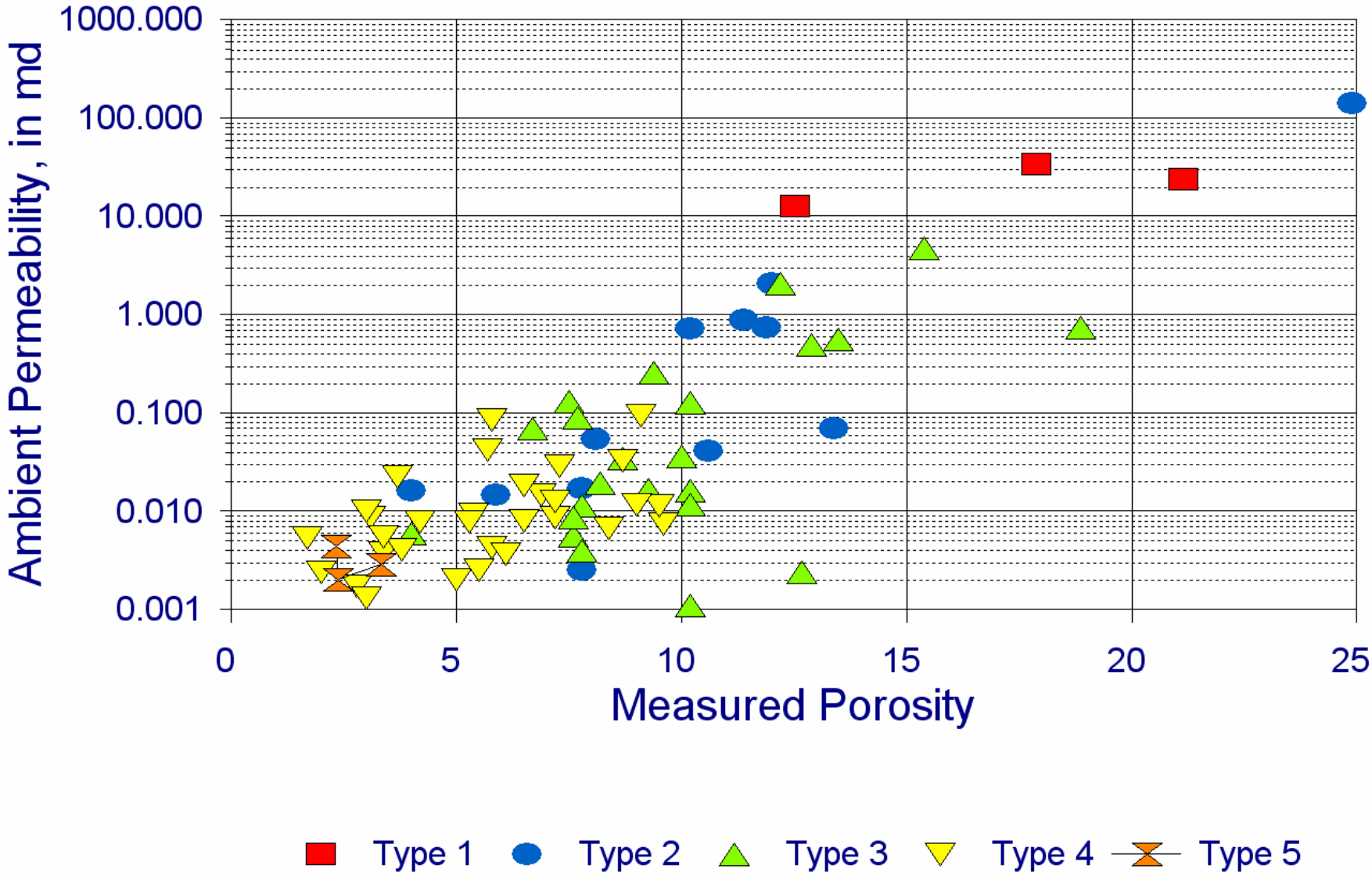
Quartz cement is prominent, ferroan calcite is sparse.

Pore-filling clay cement causes elevated Swi and reduced relative permeability.

Williams PA 424, 4686.4’ 15286
7.9% 2.65 g/cc Ka=0.211 mD

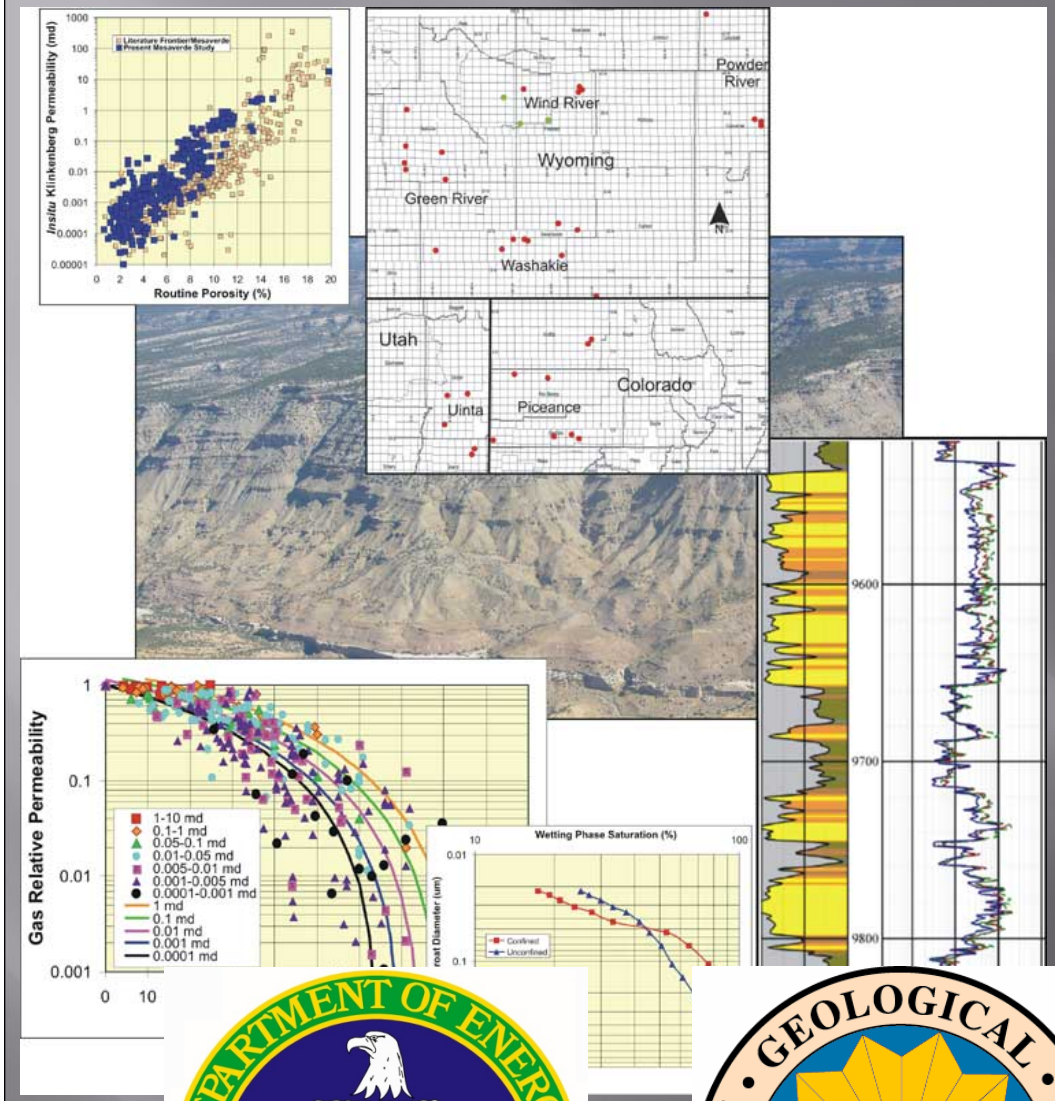
Mesaverde Group

Uinta and Piceance Basins



Conclusions

- Rock typing is useful tool for lithofacies analysis and directing statistical sampling.
- Grain size and shale content are the primary controls on reservoir quality.
- Matrix porosity in the Mesaverde Group consists of both primary and secondary intergranular, moldic and clay-filled microporosity
- Porosity type and distribution of clay cements help explain the variation of permeability for a given value of porosity.
- Microfracturing on the scale of individual grains, overgrowth partings and mesofractures are also present



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