Reservoir Characterization of Unconventional Gas Shales: Example from the Barnett Shale, Texas, U.S.A.*

Roger Slatt[1], Prerna Singh[1], Gariel Borges[2], Roderick Perez[1], Romina Portas[1], Julieta Vallejo[1], Mike Ammerman[3], William Coffey[3] and Eric Eslinger[3]

Search and Discovery Article #30075 (2009)
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Project funded by Devon Energy Company. Please see companion article on Woodford Shale, Search and Discovery Article #50147 (2009)

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Abstract

The Barnett Shale is currently one of the most active shale gas plays in the US. This unconventional shale reservoir is often considered to be homogeneous, undifferentiated black shale. Our studies show a significant, cyclical variation in the internal stratigraphy of the Barnett Shale in the core area of Newark East Field, Forth Worth Basin.

There are multiple objectives of this multidisciplinary study: (1) to develop a log- , core- and seismic-based stratigraphic framework for regional mapping of stratigraphic and petrophysical units within the area; (2) provide lithologic/mineralogic input to determine petrophysical rock properties from well logs; (3) develop a systematic workflow for characterizing gas shales; (4) provide educational opportunities for students who can then pursue gas shale studies as part of their careers. The workflow developed begins with core description (including thin section and micropaleontology) and integrating with wireline logs, followed by calibration to high resolution seismic and microseismic data.

The study area covers approximately 100 sq.miles. A detailed visual and petrographic description of long continuous core has been completed. Core lithofacies have been calibrated to logs, then identified in uncored wells using cluster analysis (GAMLSTM), which groups the rock intervals with similar multilog response. These facies have been calibrated to seismic response from 3D seismic surveys, then extended to the regional scale by seismic mapping. A stratigraphic framework was developed by analyzing lithofacies stacking patterns, then defining parasequences. Microseismic was integrated in order to identify potentially fracturable lithofacies. Ultimately an integrated geological model has been built of the study area which is at present being extended to new areas of the Barnett Shale.

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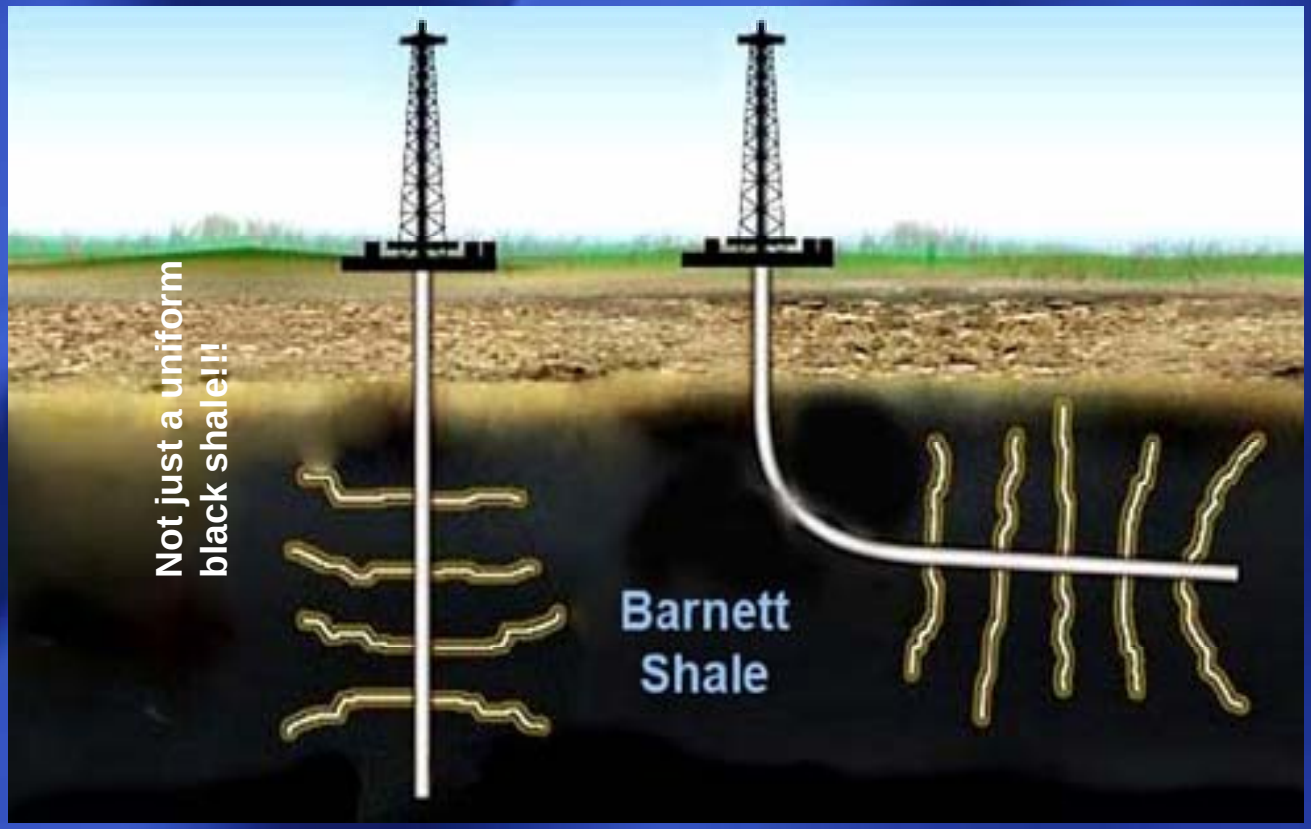
by

Roger Slatt1, Prerna Singh1, Gabriel Borges2, Roderick Perez1, Romina Portas1, Julieta Vallejo1, Mike Ammerman3, William Coffey3, and Eric Eslinger4

1 Univ. Oklahoma Conoco-Phillips School of Geology and Geophysics/ Inst. Reservoir Characterization
2 Conoco-Phillips, Inc.
3 Devon Energy Co.
4 Eric Geosciences Ltd.



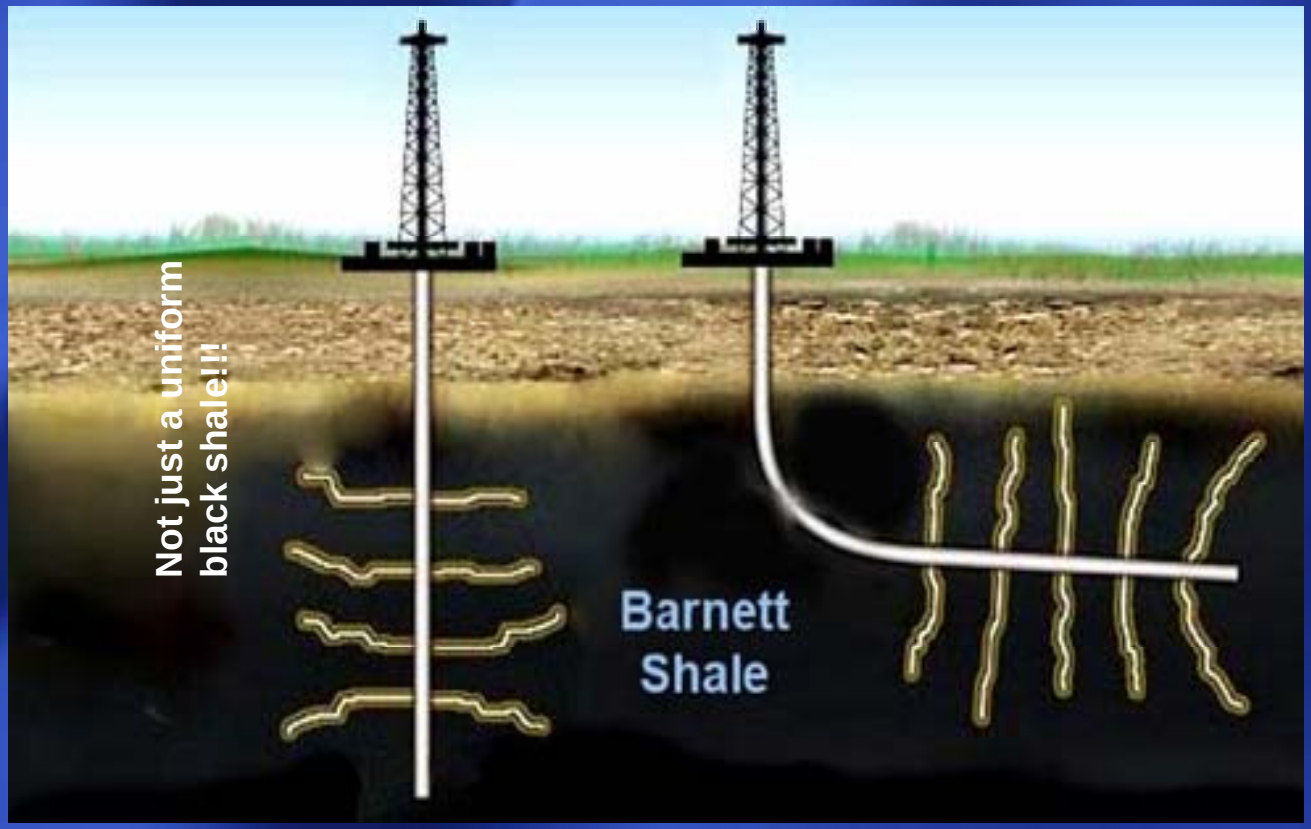
Objectives:

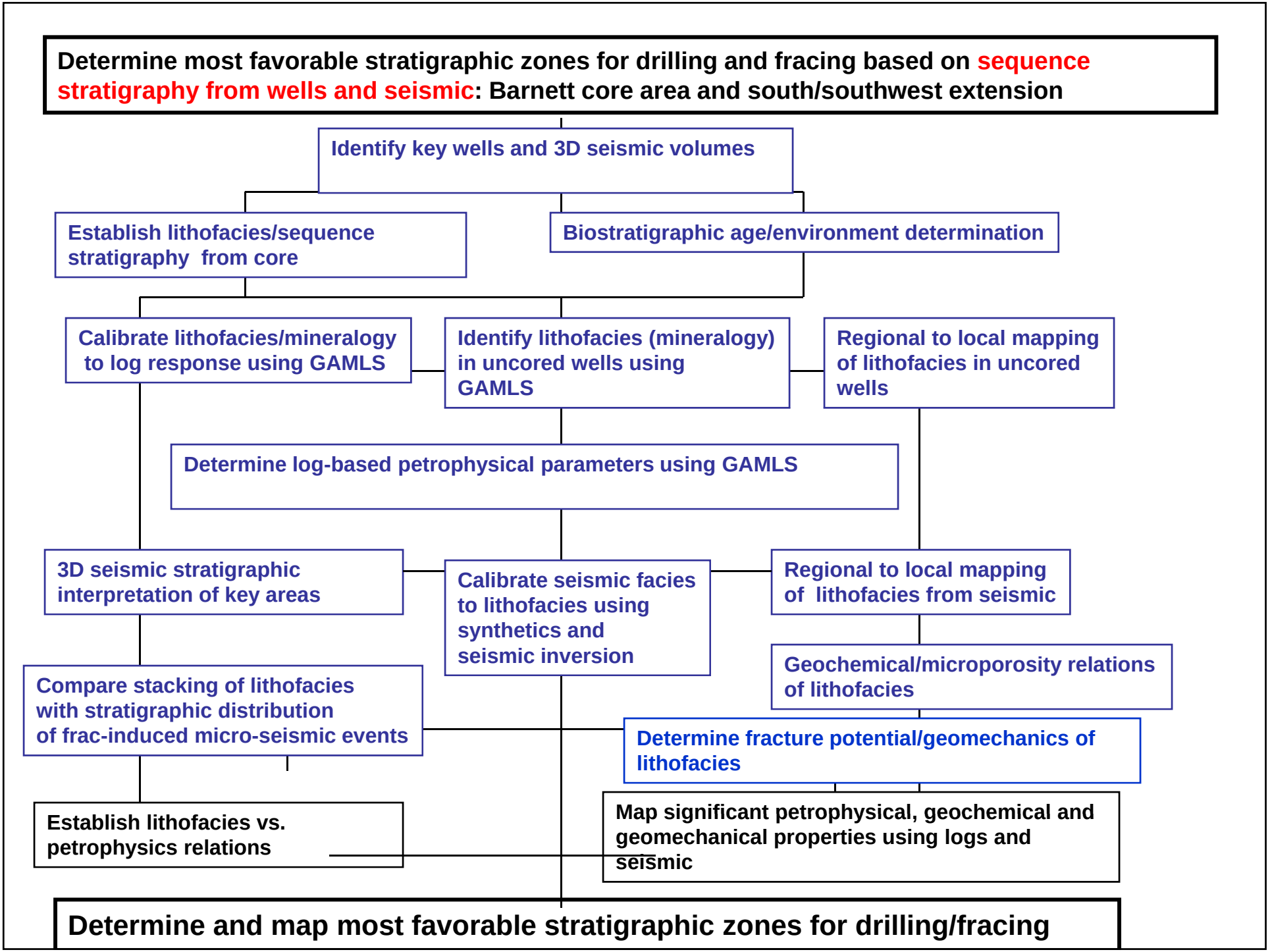
-develop log-, core-, and seismic-based stratigraphic framework for regional mapping of stratigraphic and petrophysical units; sequence stratigraphic focus;

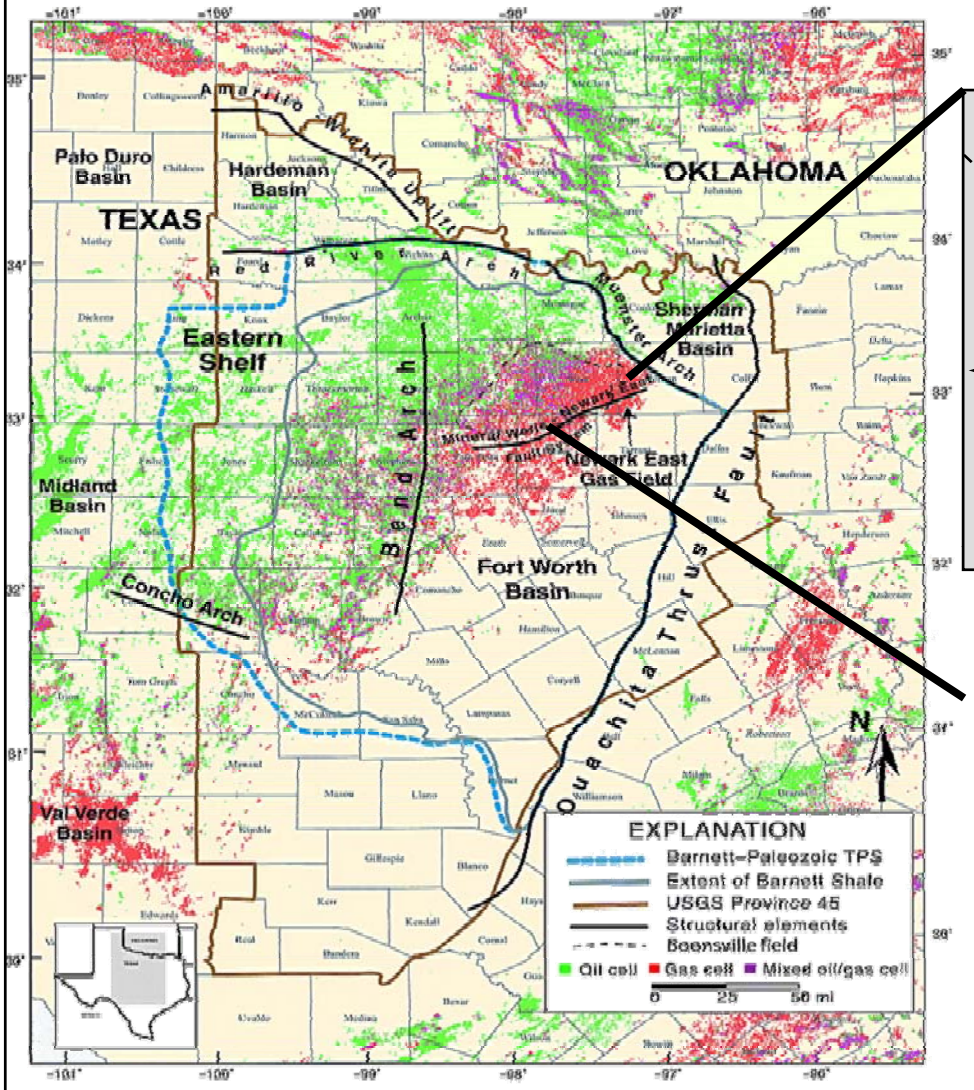
-provide lithologic/mineralogic input to determine and map petrophysical properties from well logs and seismic;

-develop systematic, integrated workflow for characterizing gas shales;

-provide educational (classroom and research) program for students to develop expertise in gas shales for petroleum industry career opportunities.

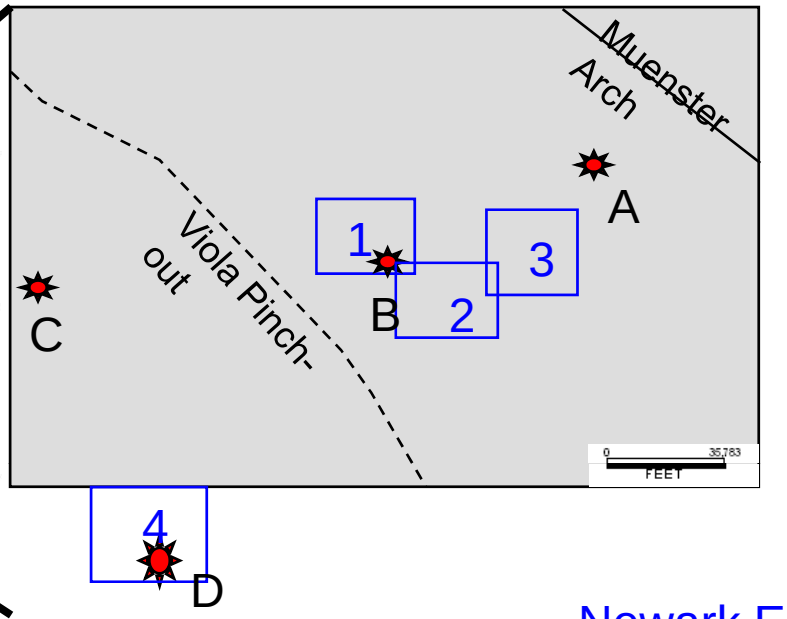



Determine most favorable stratigraphic zones for drilling and fracing based on sequence stratigraphy from wells and seismic: Barnett core area and south/southwest extension
Identify key wells and 3D seismic volumes
Establish lithofacies/sequence stratigraphy from core
Biostratigraphic age/environment determination
Calibrate lithofacies/mineralogy to log response using GAMLS
Identify lithofacies (mineralogy) in uncored wells using GAMLS
Regional to local mapping of lithofacies in uncored wells
Determine log-based petrophysical parameters using GAMLS
3D seismic stratigraphic interpretation of key areas
Calibrate seismic facies to lithofacies using synthetics and seismic inversion
Regional to local mapping of lithofacies from seismic
Geochemical/microporosity relations of lithofacies
Compare stacking of lithofacies with stratigraphic distribution of frac-induced micro-seismic events
Determine fracture potential/geomechanics of lithofacies
Establish lithofacies vs. petrophysics relations
Map significant petrophysical, geochemical and geomechanical properties using logs and seismic
Determine and map most favorable stratigraphic zones for drilling/fracing

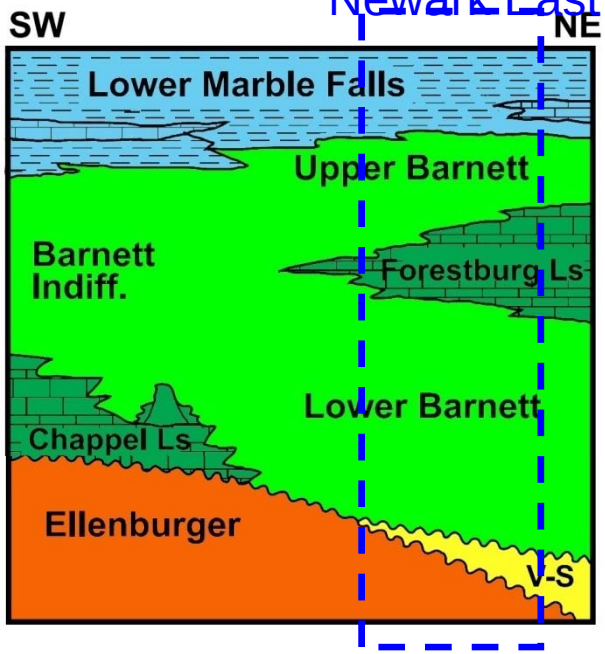


Fort Worth basin (Pollastro et al., 2007)

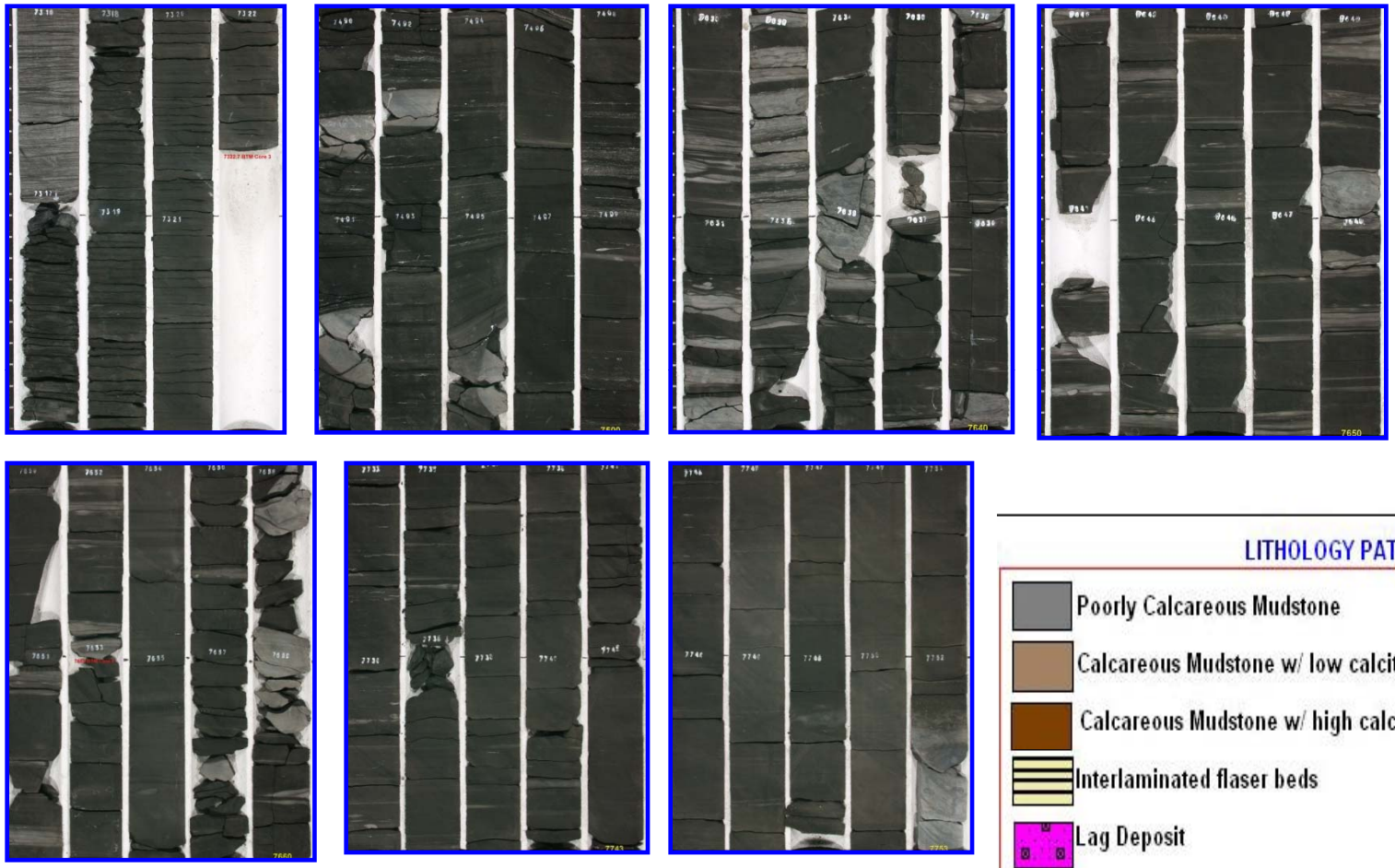
Focus area for this presentation

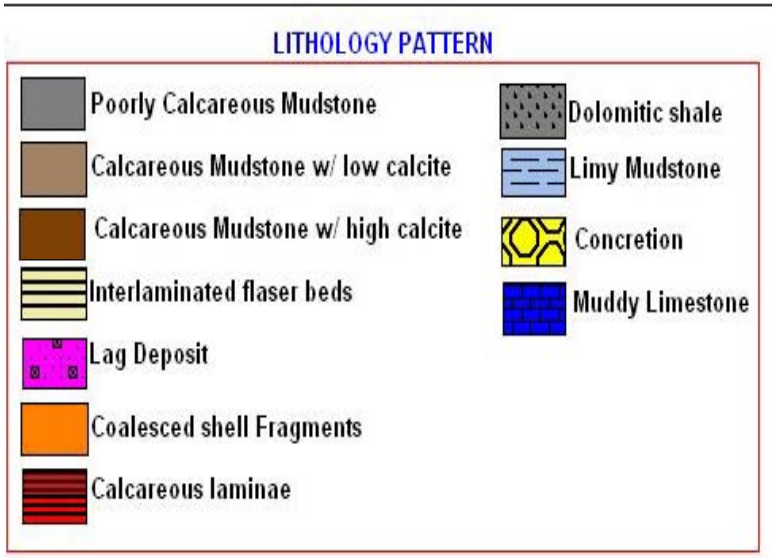


Newark East field

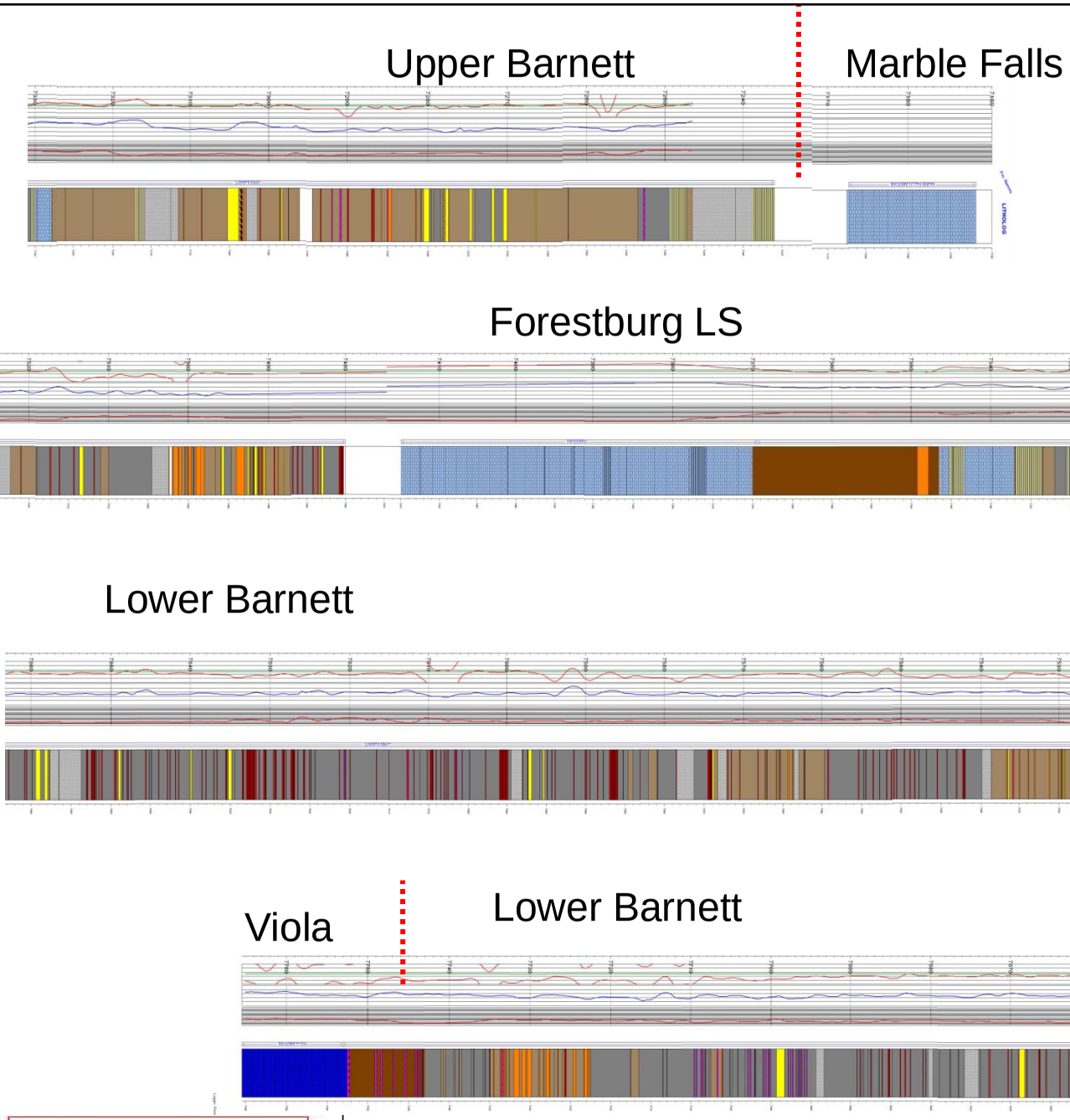


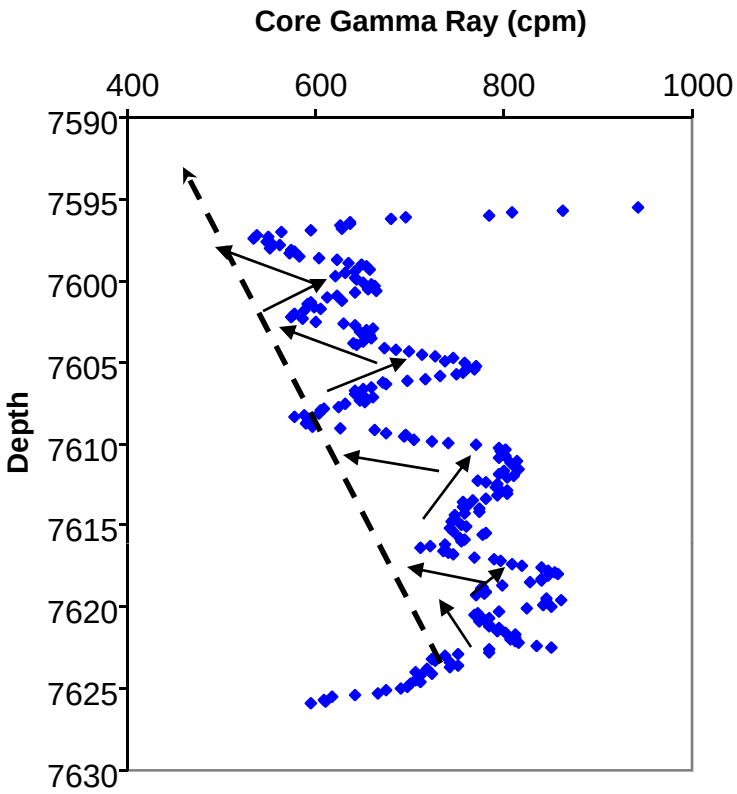
Continuous core



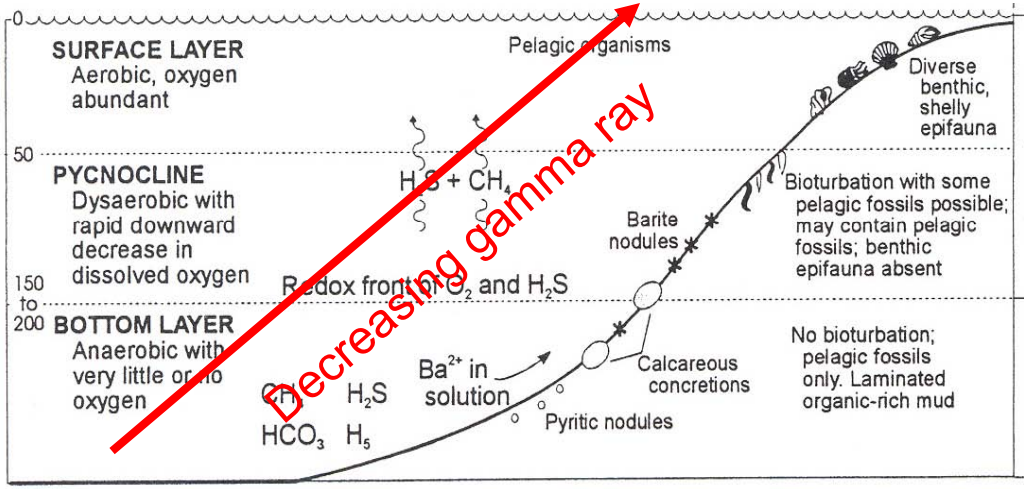


Lithologic/sequence stratigraphic characterization by P. Singh (Wednesday morning poster)


Upper Barnett
Marble Falls
Forestburg LS
Lower Barnett
Viola
Lower Barnett
LITHOLOGY PATTERN
Poorly Calcareous Mudstone
Calcareous Mudstone w/ low calcite
Calcareous Mudstone w/ high calcite
Interlaminated flaser beds
Lag Deposit
Coalesced shell Fragments
Calcareous laminae
Dolomitic shale
Limy Mudstone
Concretion
Muddy Limestone

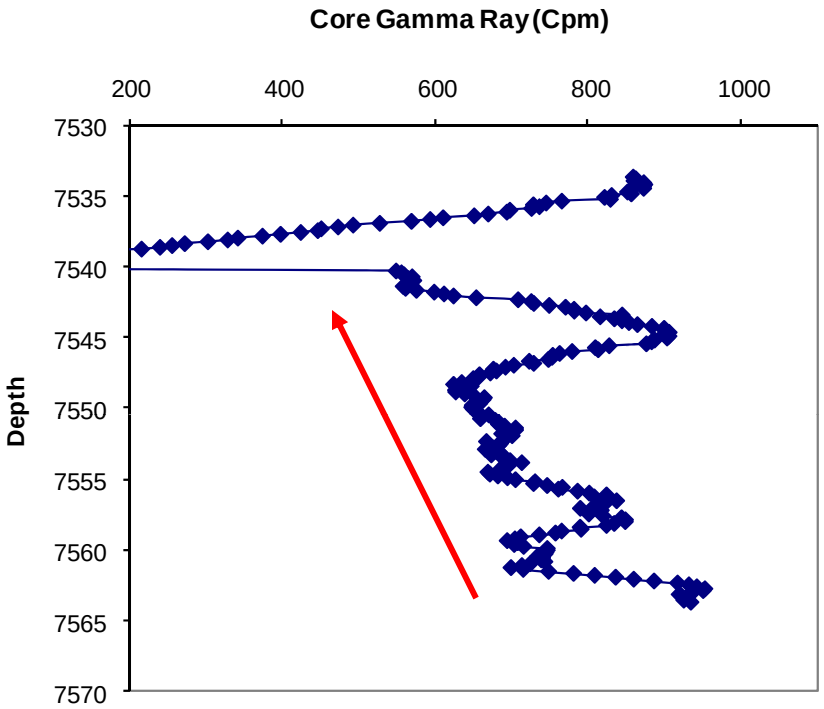


Depositional environments



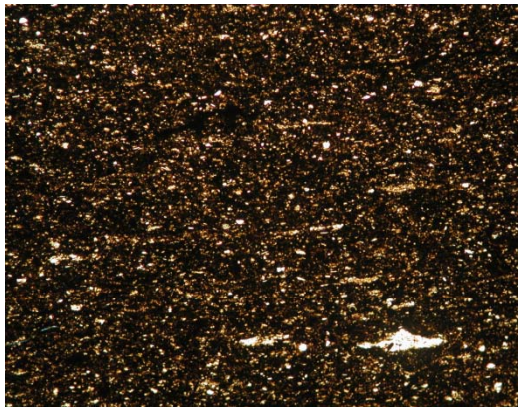
Core Gamma Scan plot for the upward – decreasing Gamma Ray parasequences from Well A. The arrows mark two scales of parasequence; the coarser scale (dashed arrow) indicates progressive shallowing of water depth over a geologic time interval, and the finer scale (solid arrows) indicate minor sea level fluctuations..

Upward-decreasing Gamma Ray parasequence



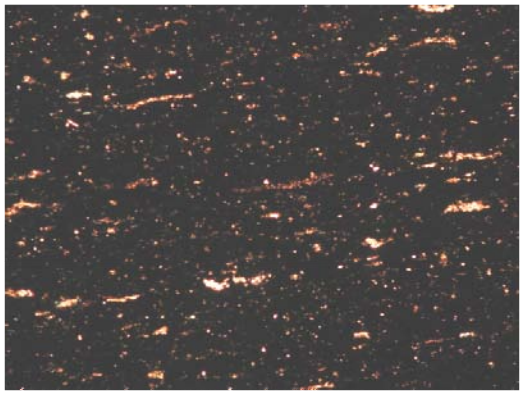
7536.5’

Top of the parasequence: Broken fragments of macrofossils and with well rounded phosphatic peloids comprising the high energy deposit: Fossiliferous deposit



7551.5’

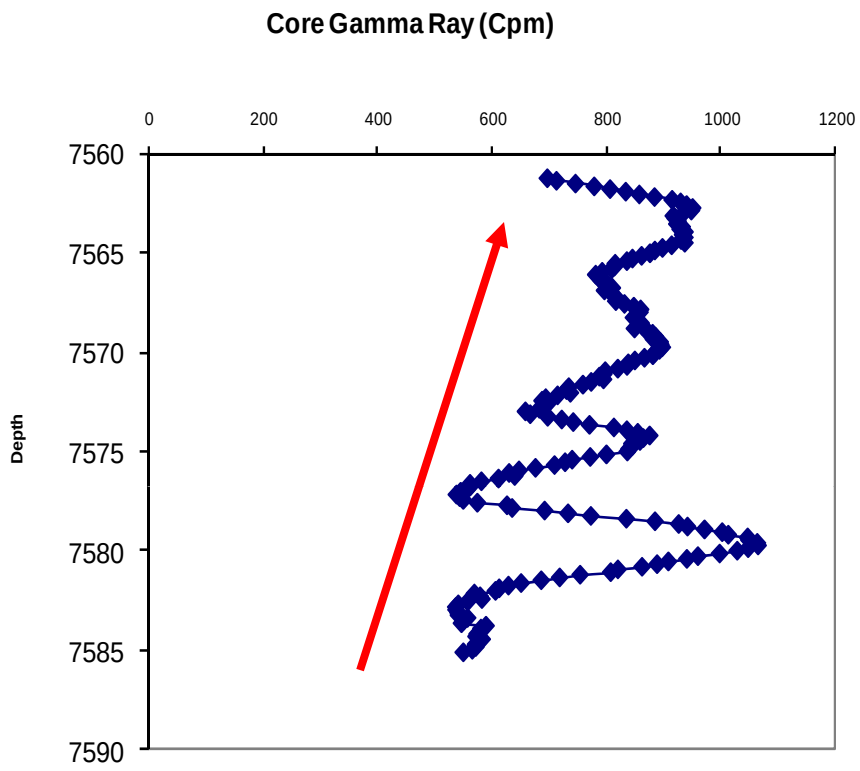
High amount of detrital quartz in the matrix.

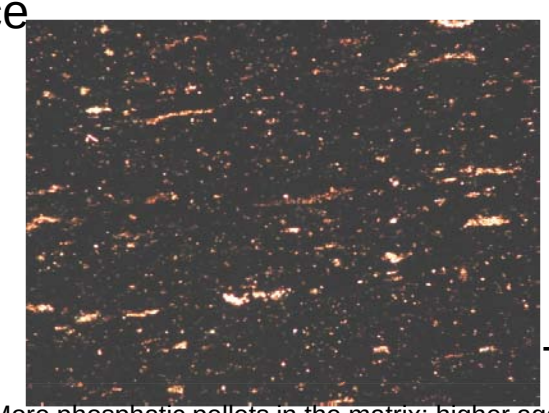


7562’

Matrix rich in phosphatic faecal pellets suggesting low sedimentation; higher agglutinated forams.

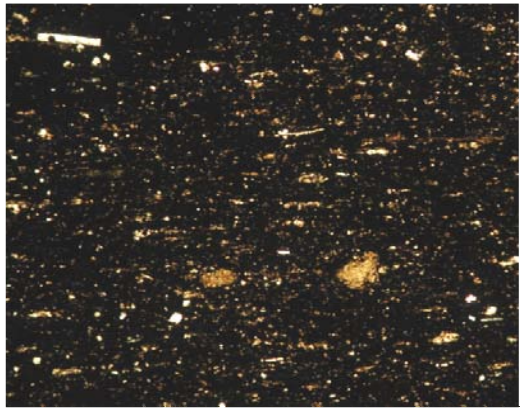
Upward-increasing Gamma Ray parasequence





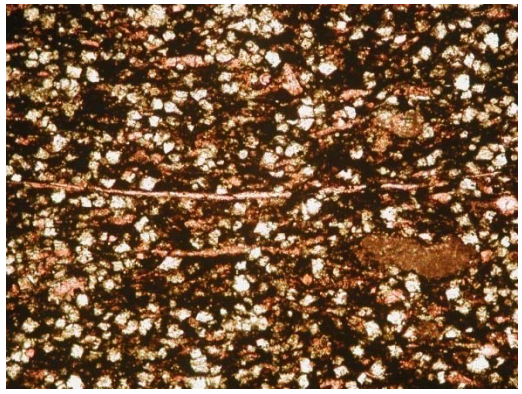
7562’

More phosphatic pellets in the matrix; higher agglutinated forams



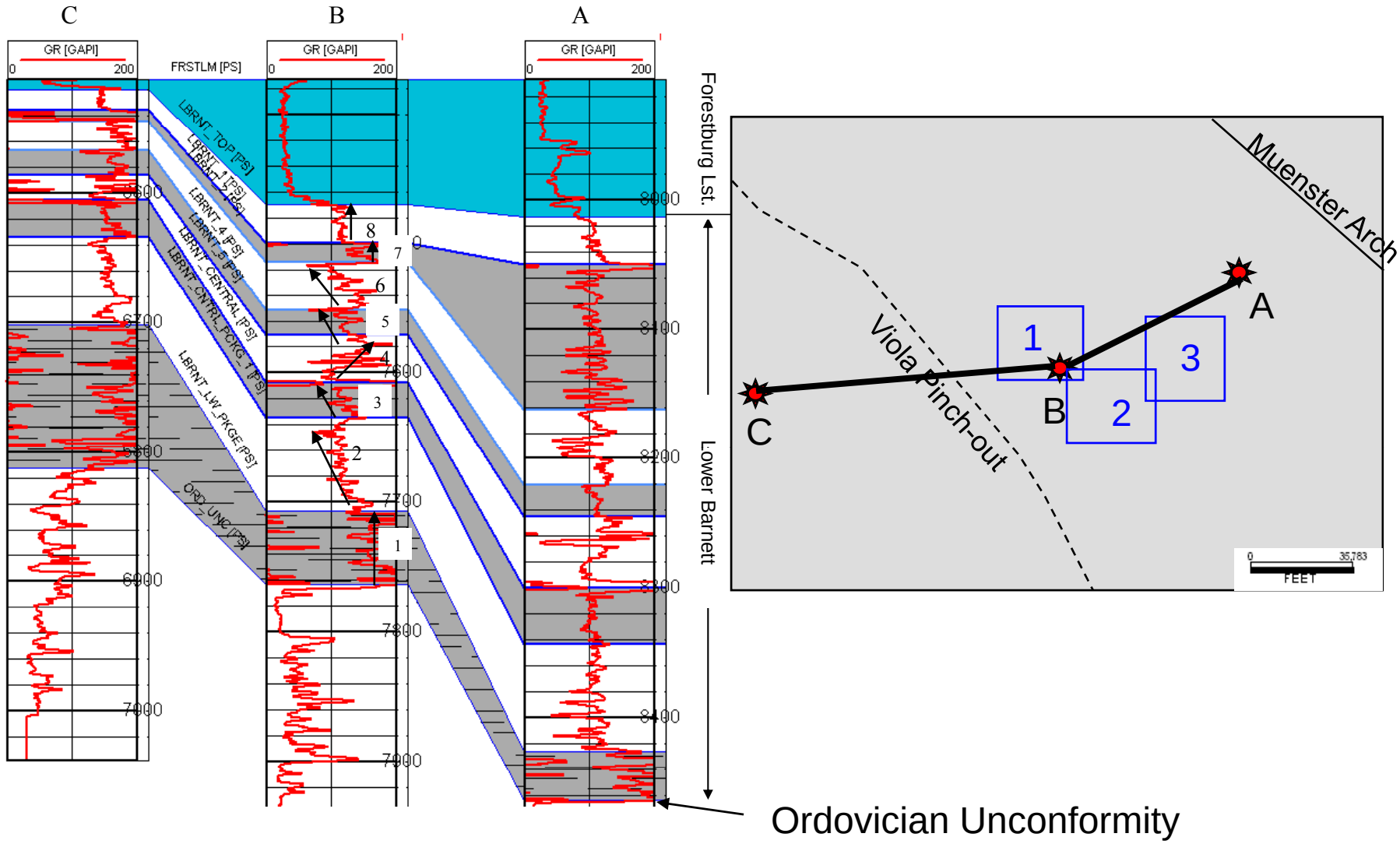
7568’

Going upsection: some detrital calcite grains

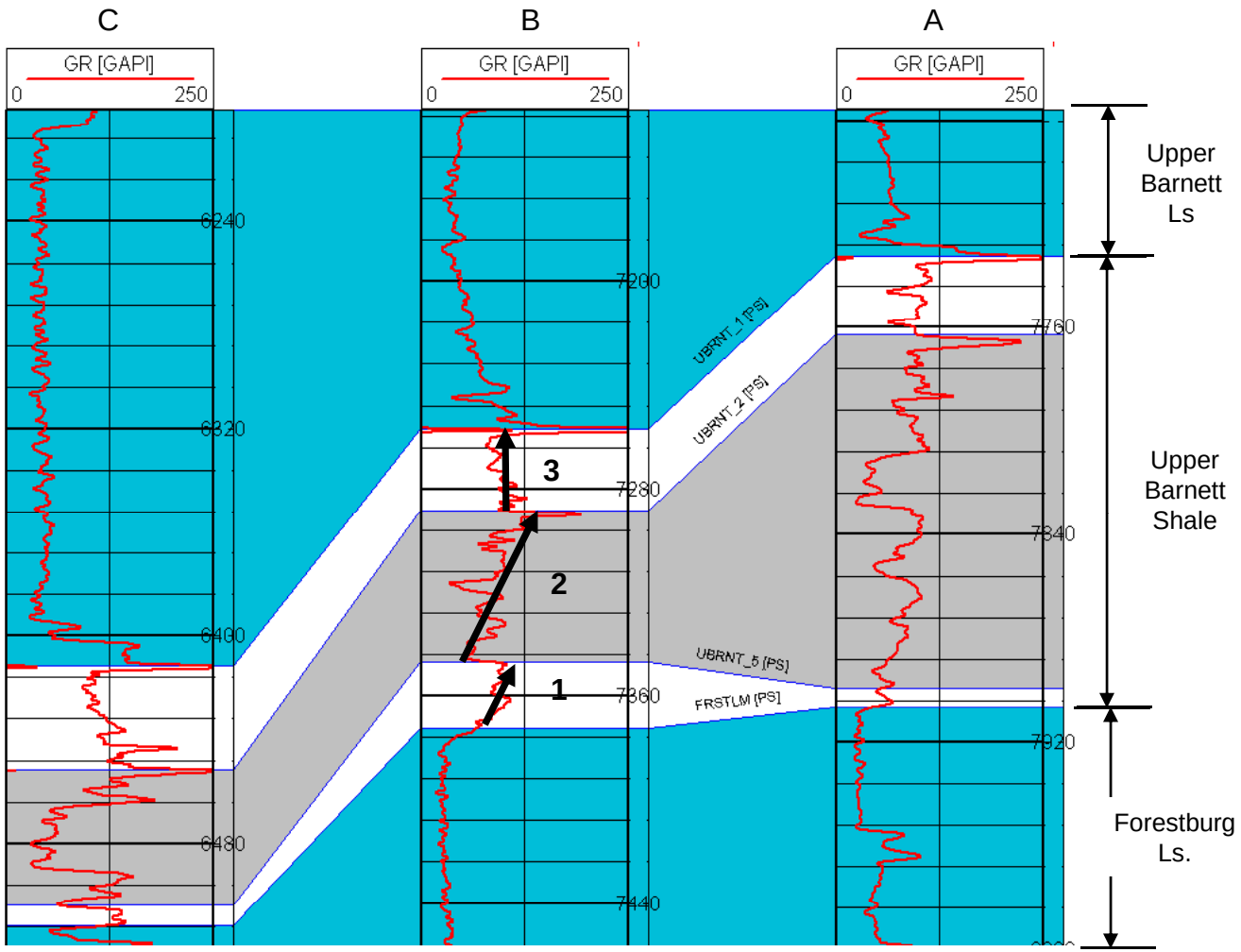


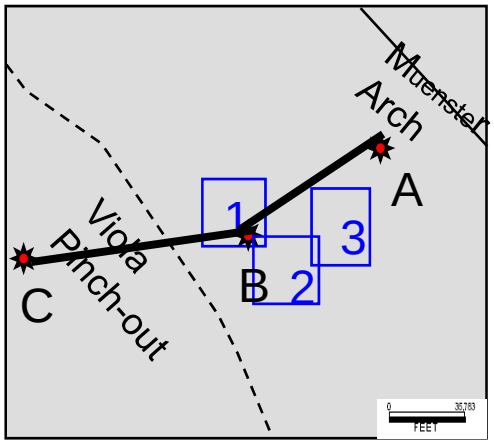
7577’

Dolomitic mudstone, highly fosssiliferous

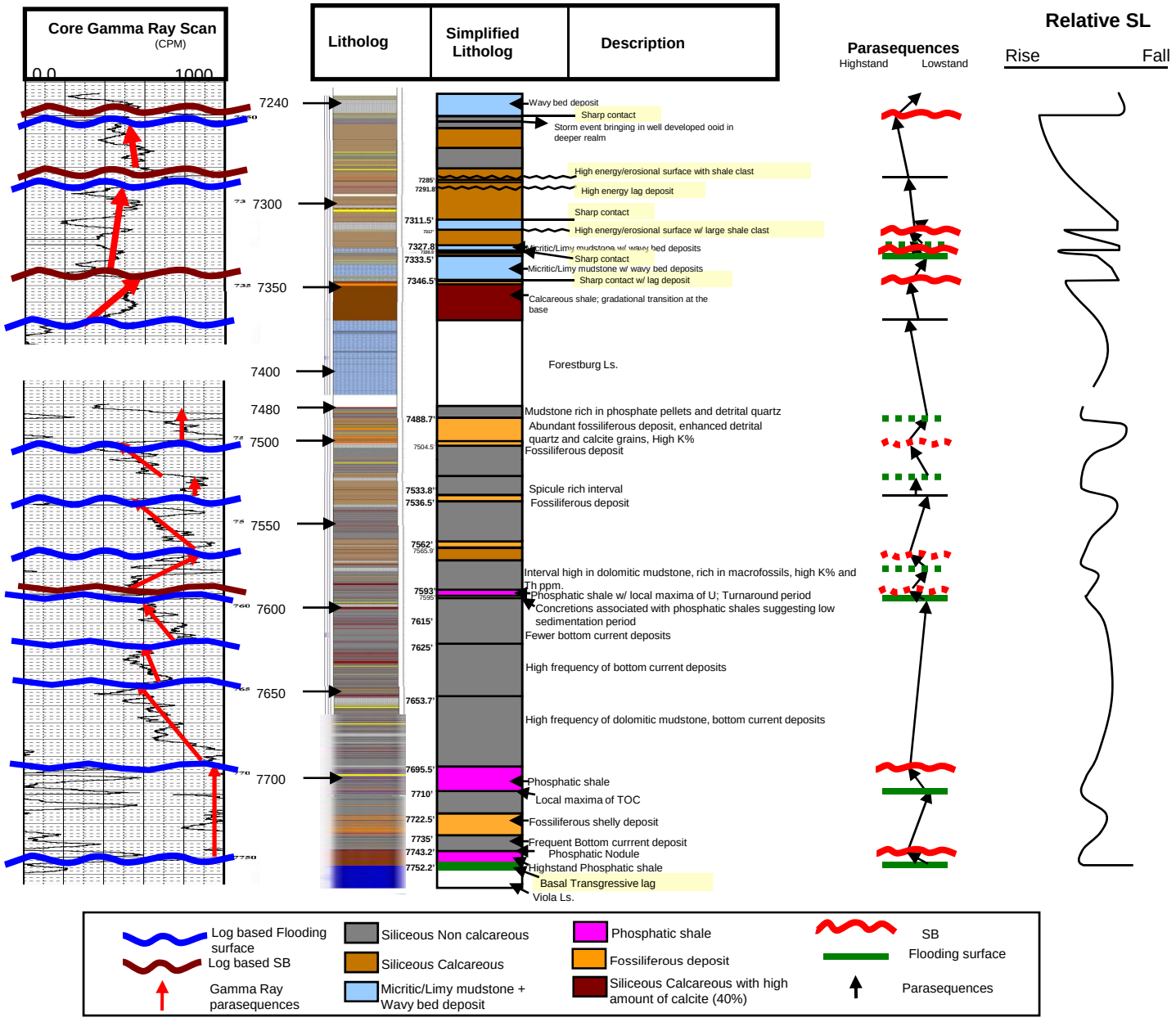


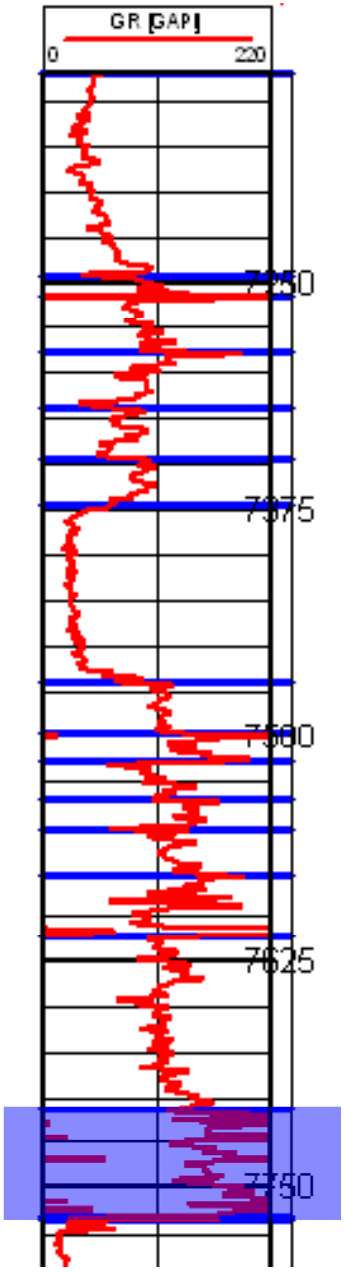
Vertical stacking pattern and lateral correlation of the Lower Barnett parasequences. The datum is the top of the Forestburg Limestone. The Gamma Ray parasequences are marked by arrows and are numbered 1-8.

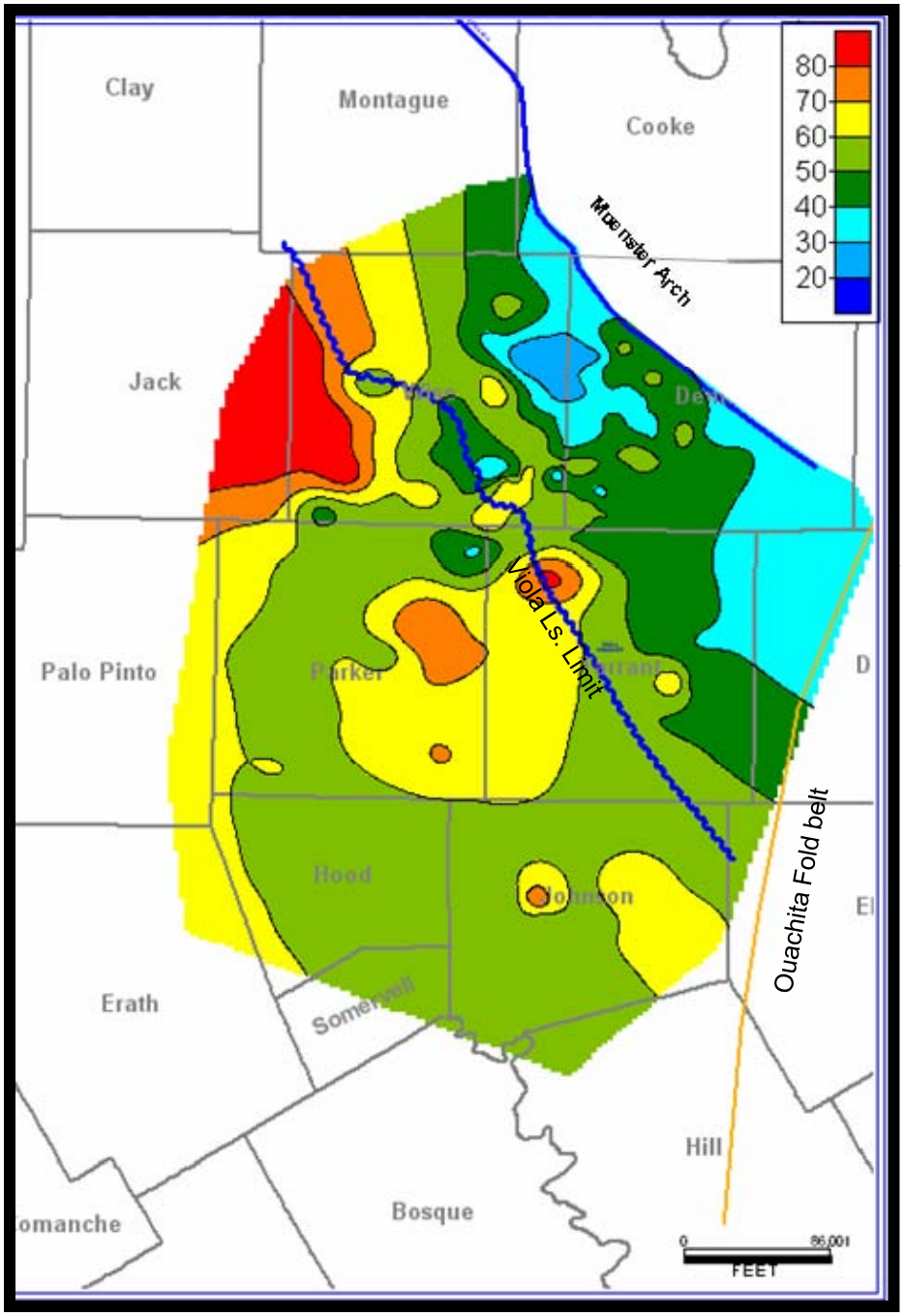


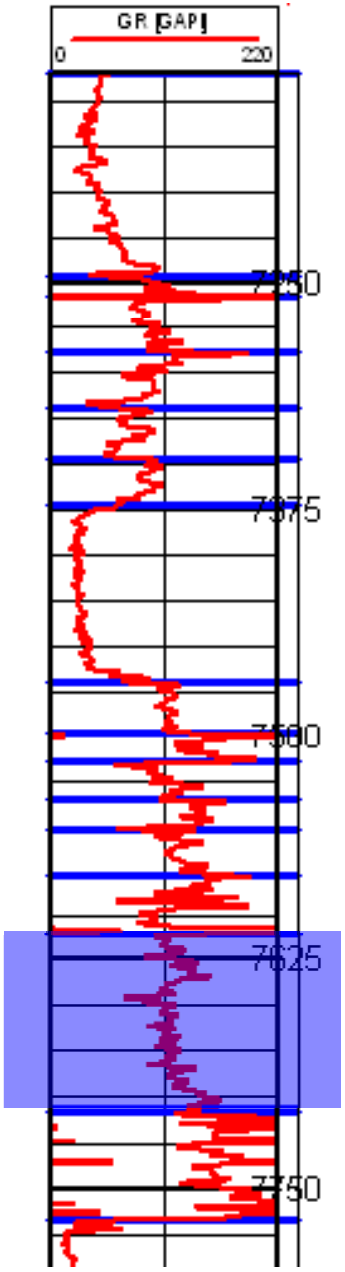


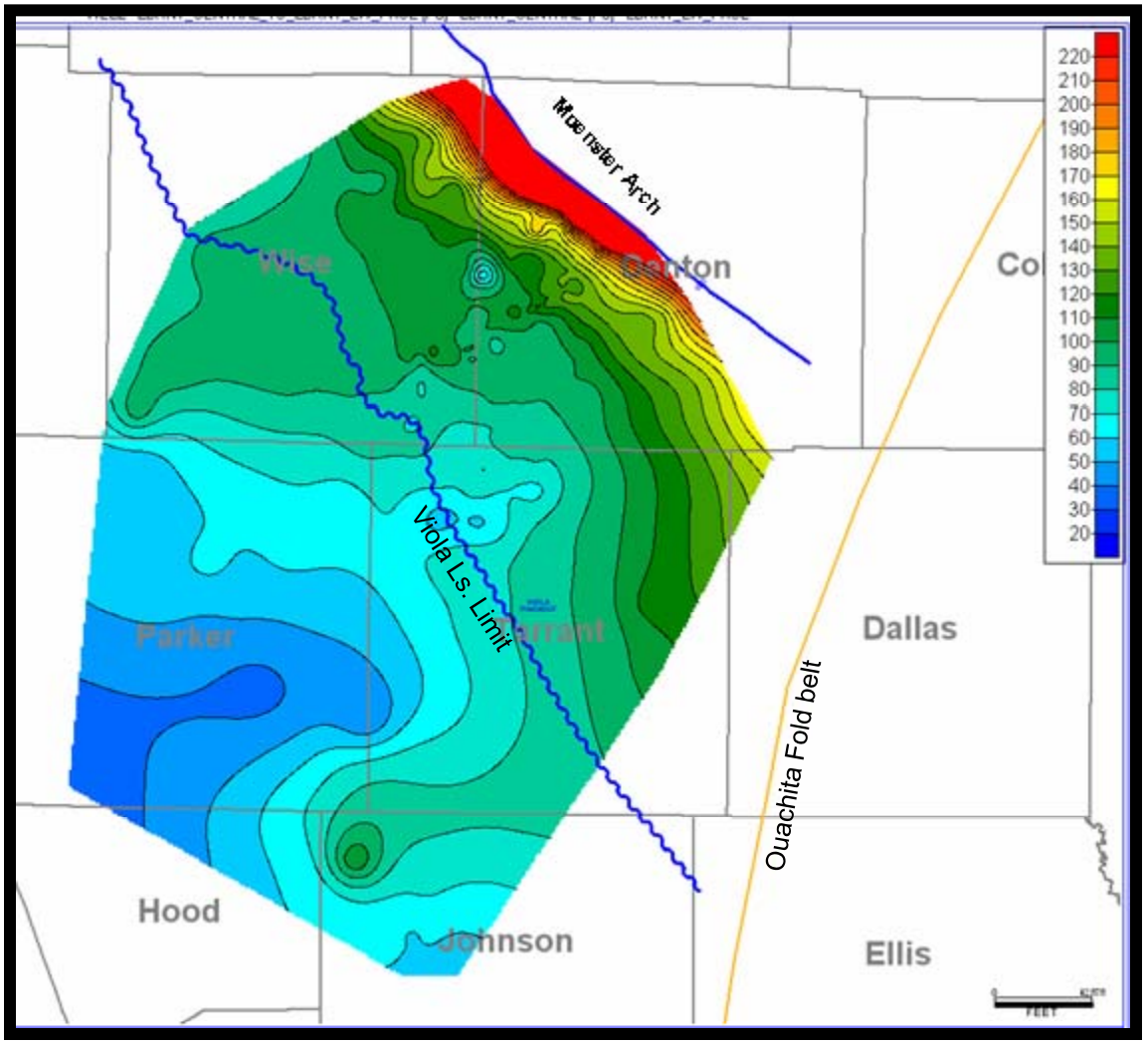
Laterally correlatable parasequences 1-3 of the **Upper Barnett** Shale. The datum used here is the top of the Upper Barnett Limestone.

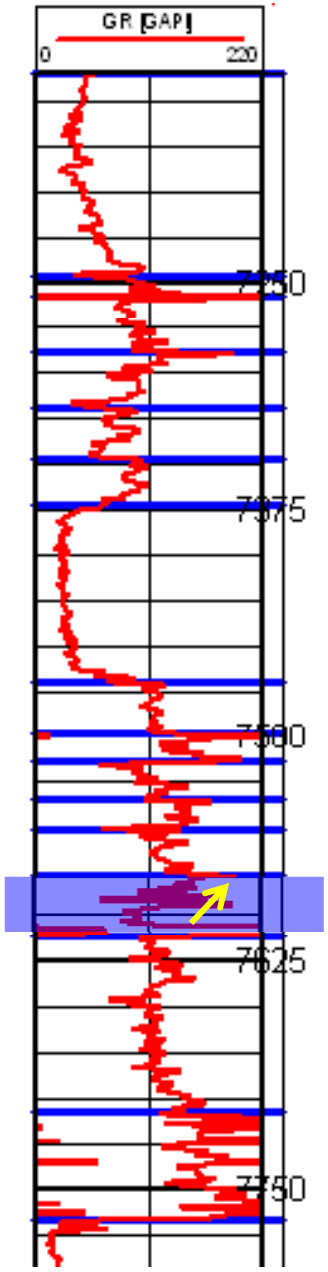

Core Gamma Ray Scan
(CPM)
0 0
1000
Litholog
Simplified Litholog
Description
Parasequences
Highstand
Lowstand
Relative SL
Rise
Fall
7240
7300
7350
7400
7480
7500
7550
7600
7650
7700
Wavy bed deposit
Sharp contact
Storm event bringing in well developed ooid in deeper realm
7285'
7291.8
High energy/erosional surface with shale clast
High energy lag deposit
7311.5'
Sharp contact
High energy/erosional surface w/ large shale clast
7327.8
7333.5'
Micritic/Limy mudstone w/ wavy bed deposits
Sharp contact
Micritic/Limy mudstone w/ wavy bed deposits
7346.5'
Sharp contact w/ lag deposit
Calcareous shale; gradational transition at the base
Forestburg Ls.
Mudstone rich in phosphate pellets and detrital quartz
7488.7'
Abundant fossiliferous deposit, enhanced detrital quartz and calcite grains, High K%
7504.5
Fossiliferous deposit
7533.8'
Spicule rich interval
7536.5'
Fossiliferous deposit
7562'
7565.9
Interval high in dolomitic mudstone, rich in macrofossils, high K% and Th ppm.
7593'
7595
Phosphatic shale w/ local maxima of U; Turnaround period
Concretions associated with phosphatic shales suggesting low sedimentation period
7615'
Fewer bottom current deposits
7625'
High frequency of bottom current deposits
7653.7'
High frequency of dolomitic mudstone, bottom current deposits
7695.5'
Phosphatic shale
7710'
Local maxima of TOC
7722.5'
Fossiliferous shelly deposit
7735'
Frequent Bottom currrent deposit
7743.2'
Phosphatic Nodule
7752.2'
Highstand Phosphatic shale
Basal Transgressive lag
Viola Ls.
Log based Flooding surface
Log based SB
Gamma Ray parasequences
Siliceous Non calcareous
Siliceous Calcareous
Micritic/Limy mudstone + Wavy bed deposit
Phosphatic shale
Fossiliferous deposit
Siliceous Calcareous with high amount of calcite (40%)
SB
Flooding surface
Parasequences

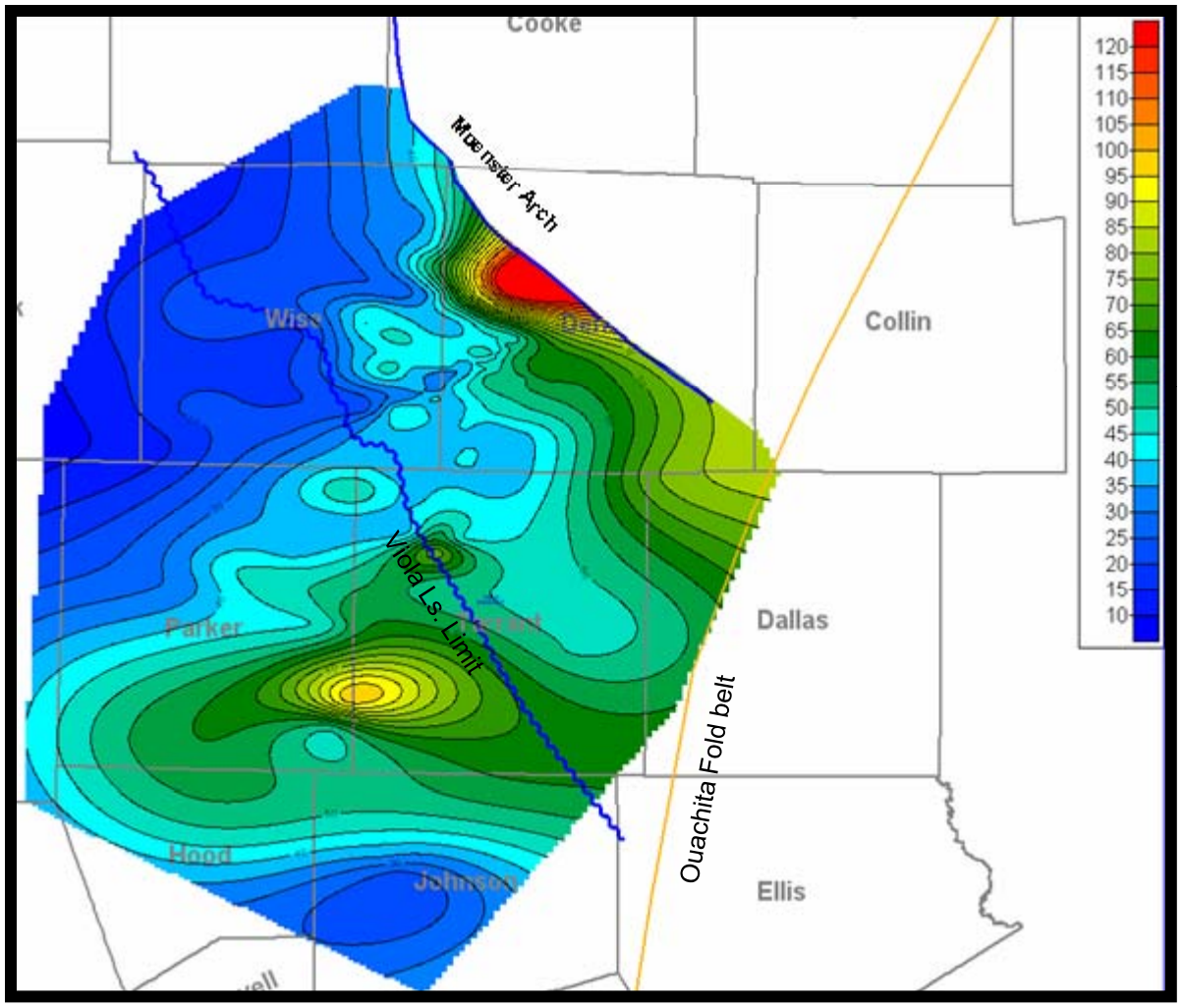

GR [API]
0
220
7550
7575
7600
7625
7650


80
70
60
50
40
30
20
Clay
Montague
Cooke
Jack
Palo Pinto
Parker
Hood
Johnson
Erath
Somervell
Hill
Bosque
omanche
Muenster Arch
Viola Ls. Limit
Ouachita Fold belt
0
86,001
FEET

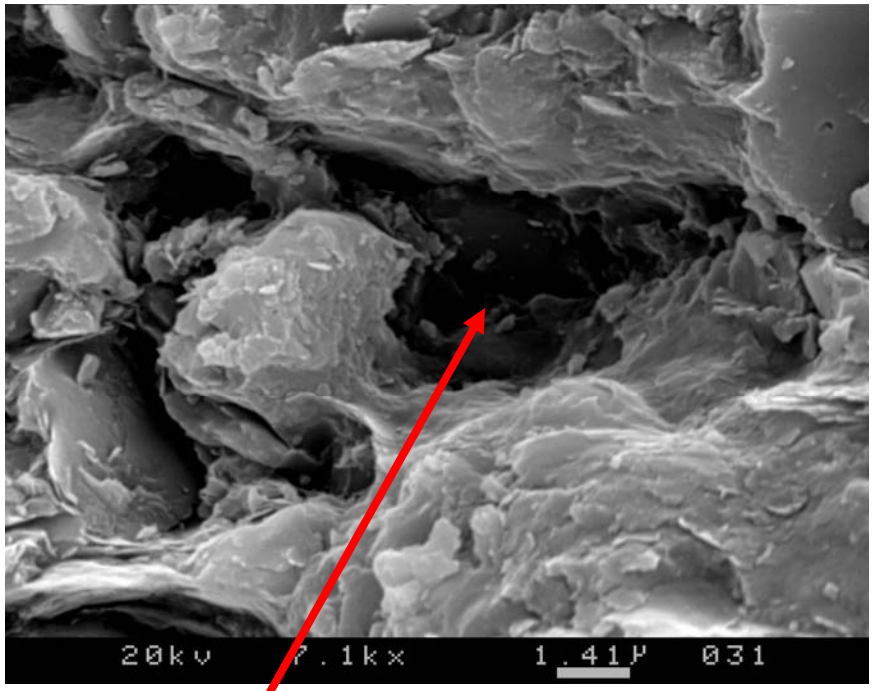

GR (API)
0
220
7250
7375
7500
7625
7750


Muenster Arch
Wise
Denton
Parker
Tarrant
Dallas
Hood
Johnson
Ellis
Viola Ls. Limit
Ouachita Fold belt
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20


GR [GAPI]
0
220
7250
7375
7500
7625
7750

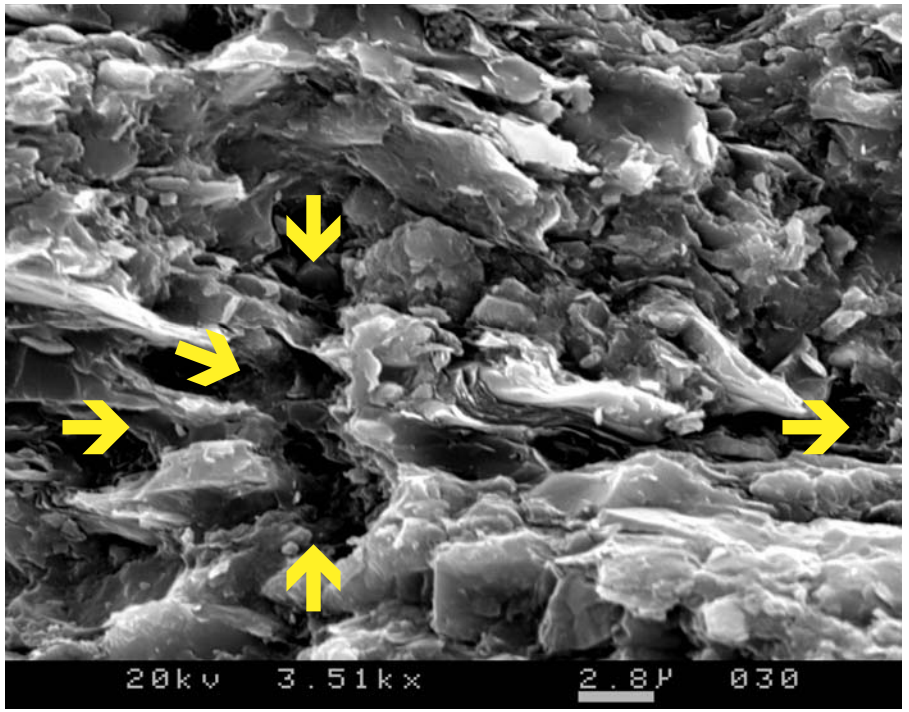

Cooke
Muenster Arch
Wise
Collin
Dallas
Parker
Viola Ls. Limit
Ouachita Fold belt
Hood
Johnson
Ellis
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10

Microfabric (SEM) in Barnett Shale

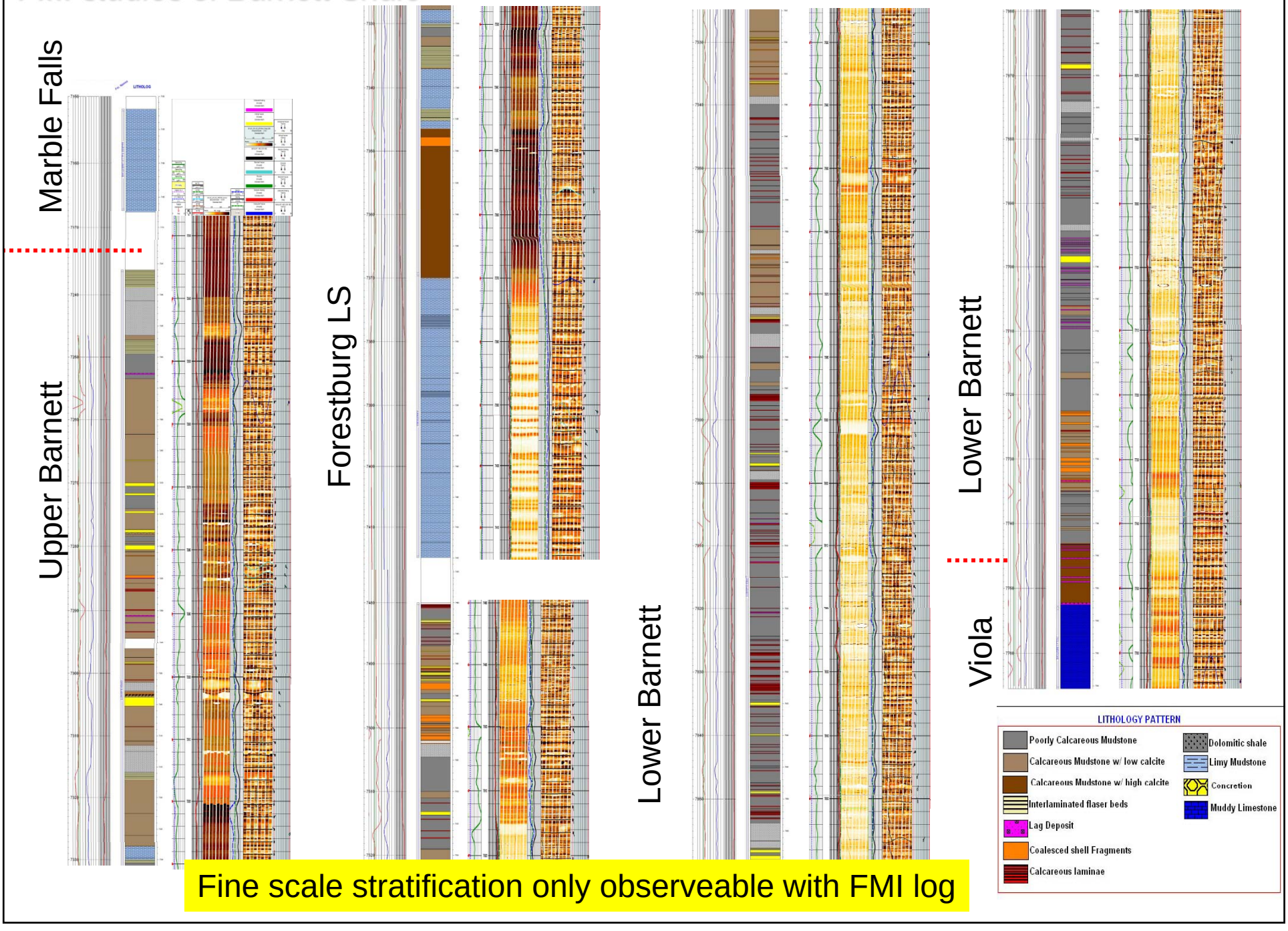


Pore space

-Migration pathways??
-Preferential planes of weakness??

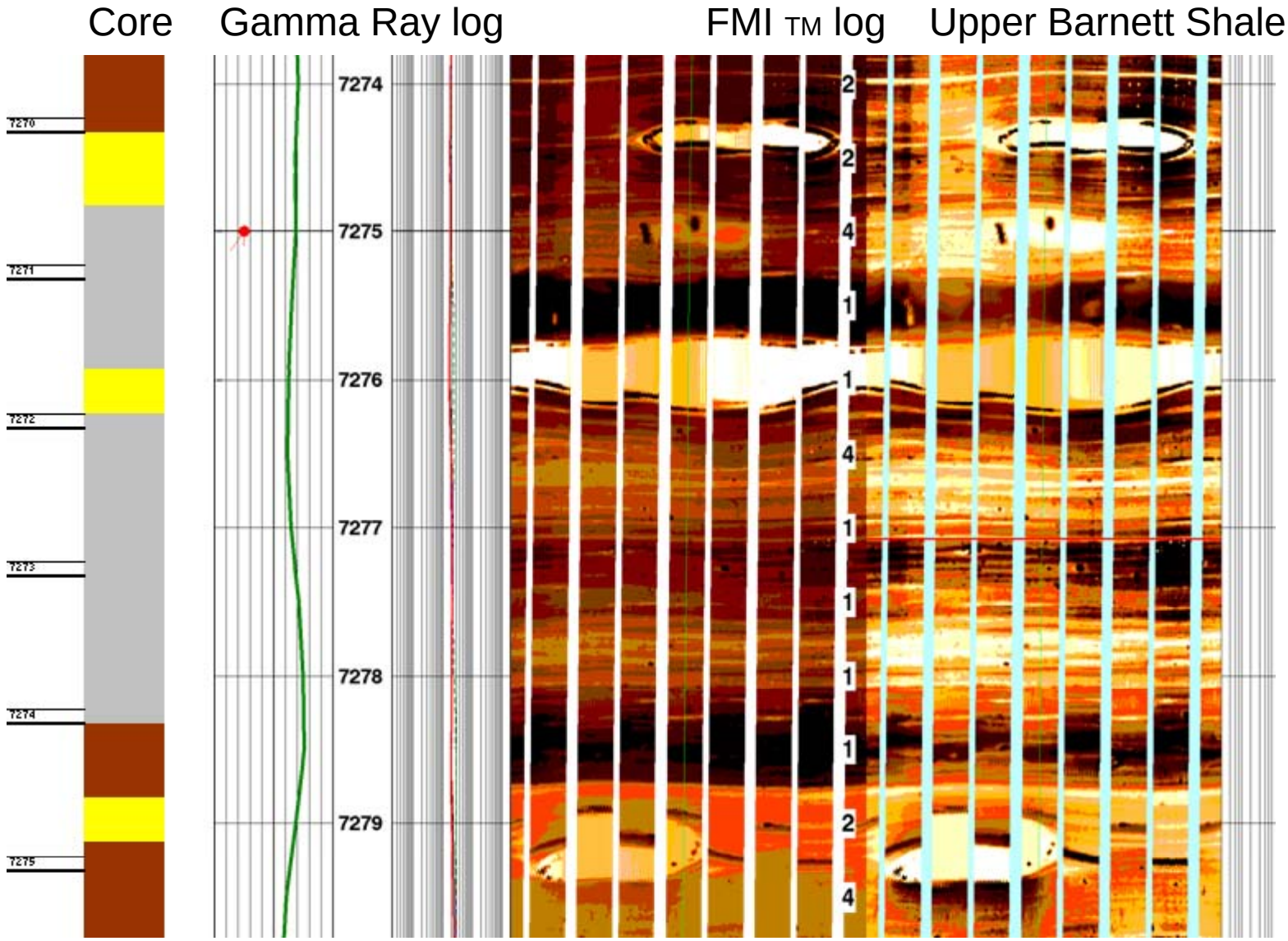


FMI studies of Barnett Shale



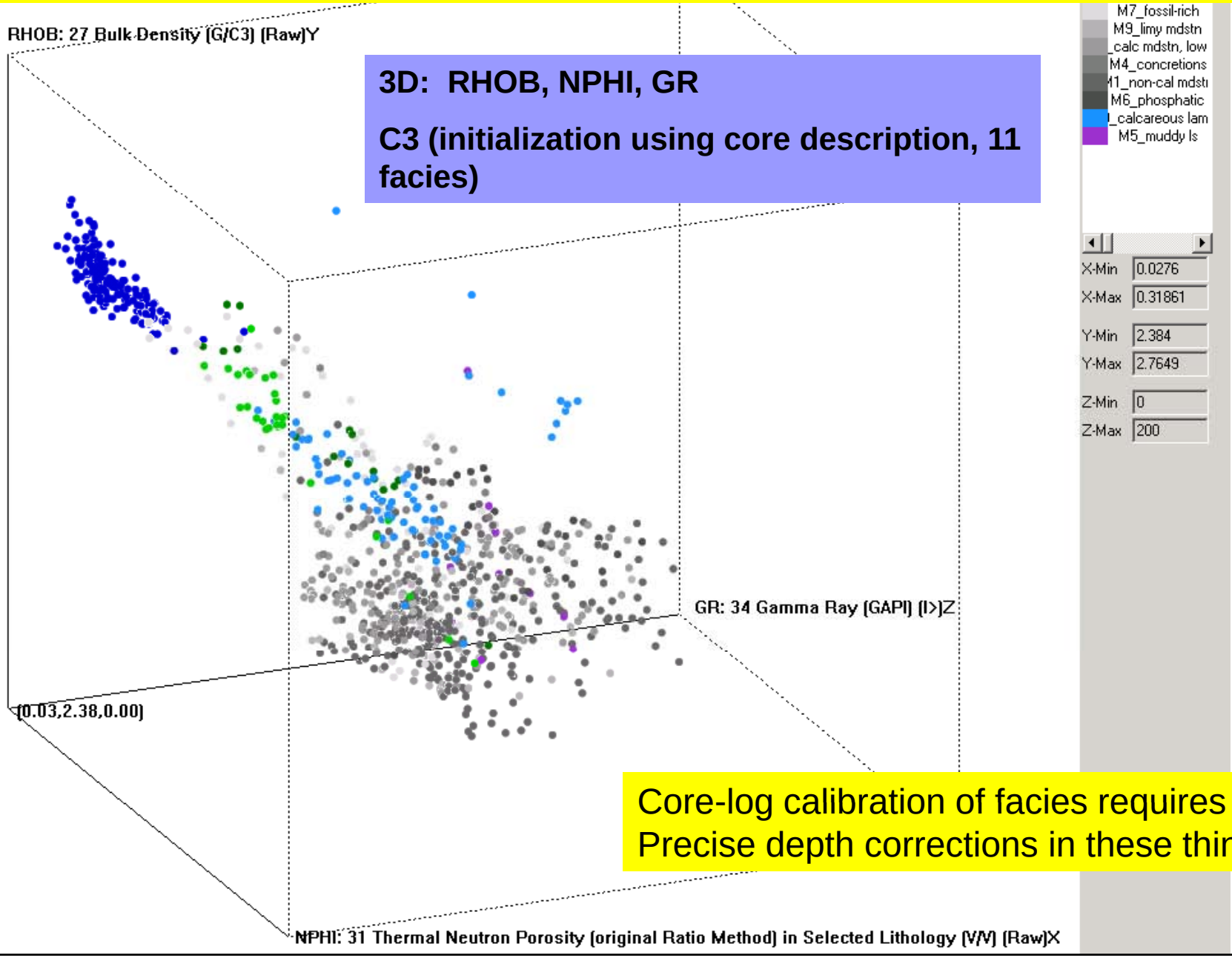
Fine scale stratification only observeable with FMI log

Determining fine-scale lithofacies in uncored wells???

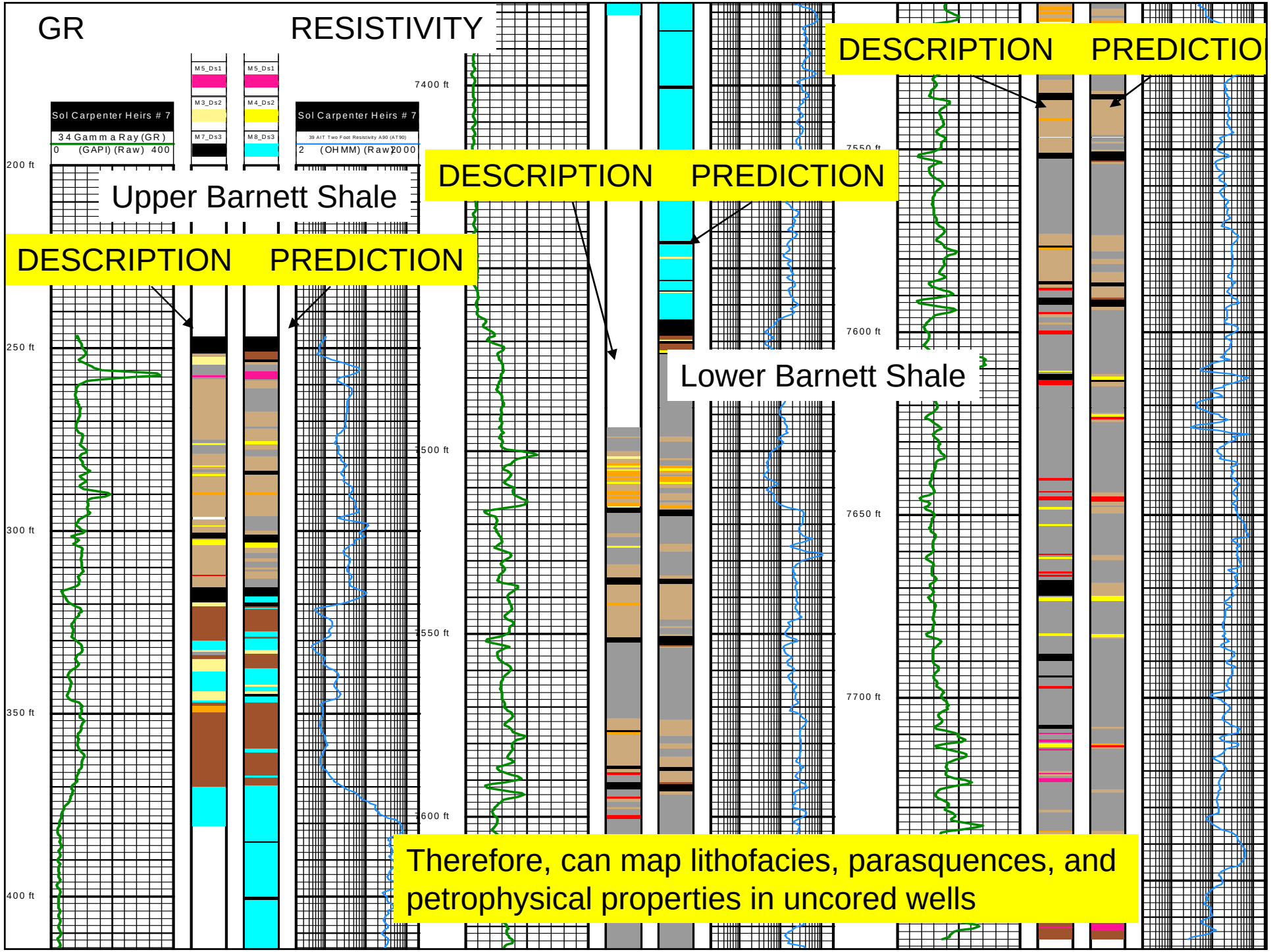


Concretions: (yellow) white (resistive)

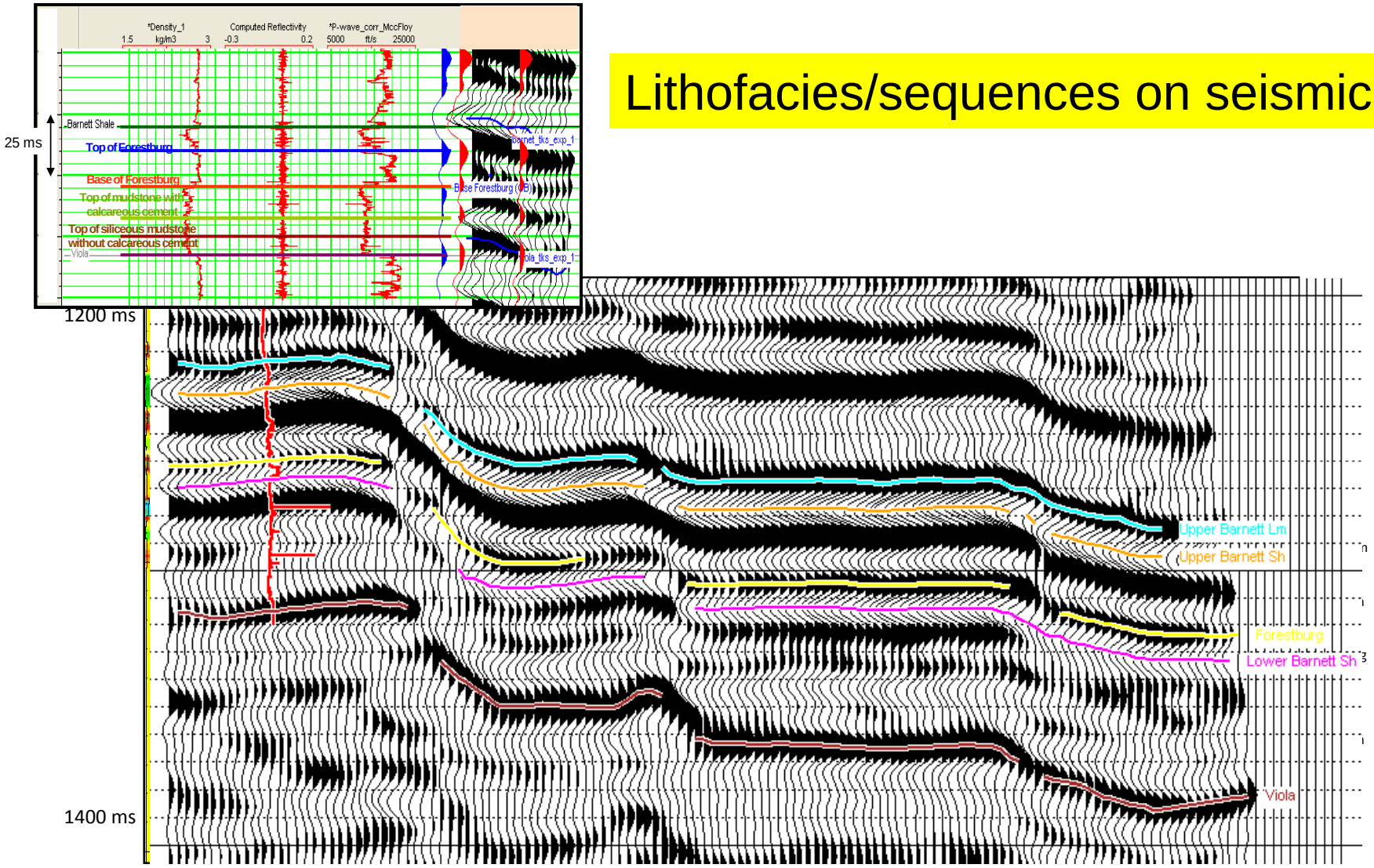
GAMLS: Geological Analysis via Maximum Likelihood System



Core-log calibration of facies requires
Precise depth corrections in these thin beds!!

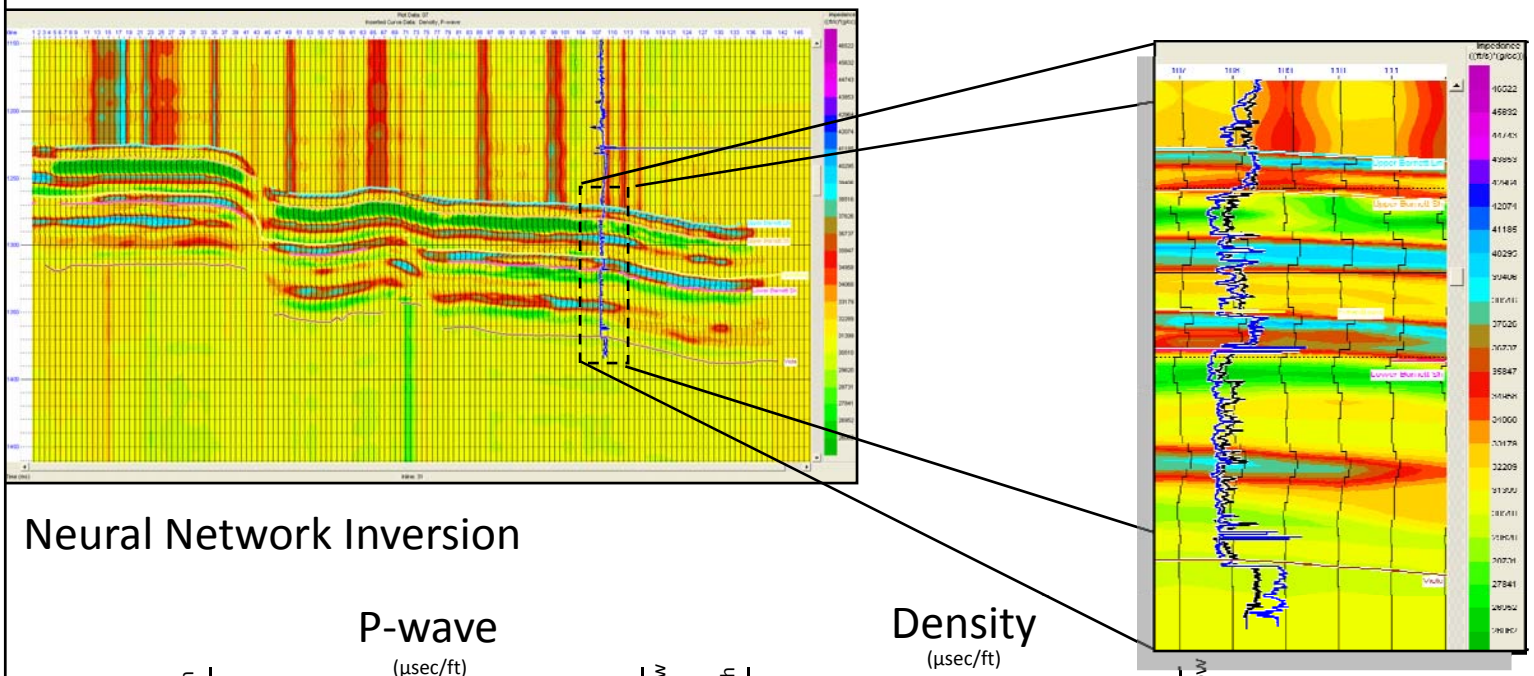

GR
RESISTIVITY
DESCRIPTION
PREDICTIO
Sol Carpenter Heirs # 7
34 Gamma Ray (GR)
0 (GAPI) (Raw) 400
Sol Carpenter Heirs # 7
39 AIT Two Foot Resistivity A90 (AT90)
2 (OHMM) (Raw) 2000
M5_Ds1
M3_Ds2
M7_Ds3
M5_Ds1
M4_Ds2
M8_Ds3
200 ft
250 ft
300 ft
350 ft
400 ft
7400 ft
7500 ft
7550 ft
7600 ft
7650 ft
7700 ft
7600 ft
Upper Barnett Shale
DESCRIPTION PREDICTION
DESCRIPTION PREDICTION
Lower Barnett Shale
Therefore, can map lithofacies, parasquences, and
petrophysical properties in uncored wells

Lithofacies/sequences on seismic??



*Click on image to see inversion results.

Neural Network Inversion



Neural Network Inversion

P-wave
(µsec/ft)

Density
(µsec/ft)

high
low

Upper Barnett Lm
Upper Barnett Sh
Forestburg
Lower Barnett Sh

Objectives: Have been met!!!!!!!

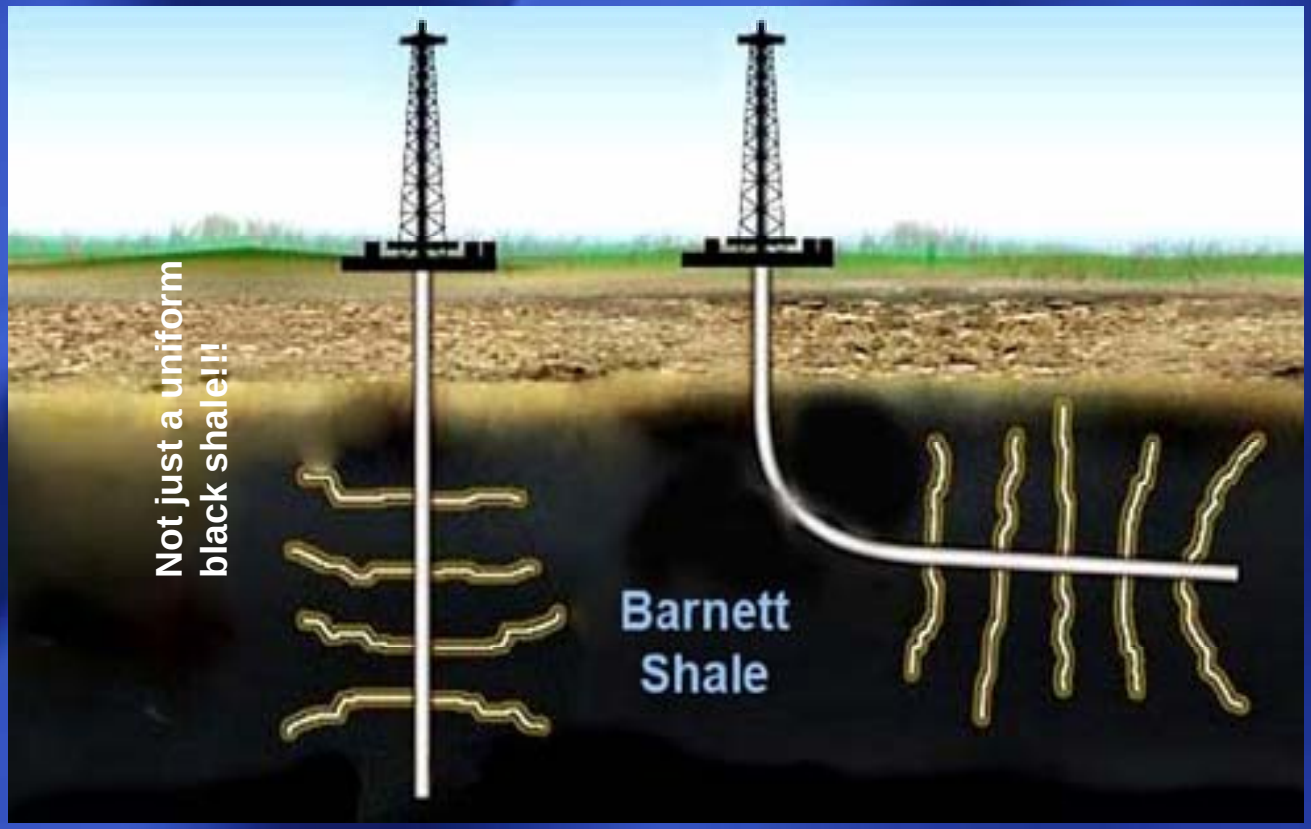
-develop log-, core- and seismic-based stratigraphic framework for regional mapping of stratigraphic and petrophysical units; sequence stratigraphic focus;

-provide lithologic/mineralogic input to determine and map petrophysical properties from well logs and seismic;

-develop systematic, integrated workflow for characterizing gas shales;

-provide educational (classroom and research) program for students to develop expertise in gas shales for petroleum industry career opportunities.

Companion article on Woodford Shale (Search and Discovery Article # 50147 (2009))



Reference

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