Geologic model for the giant Hugoton and Panoma Fields

Martin K. Dubois
Alan P. Byrnes
Geoffrey C. Bohling

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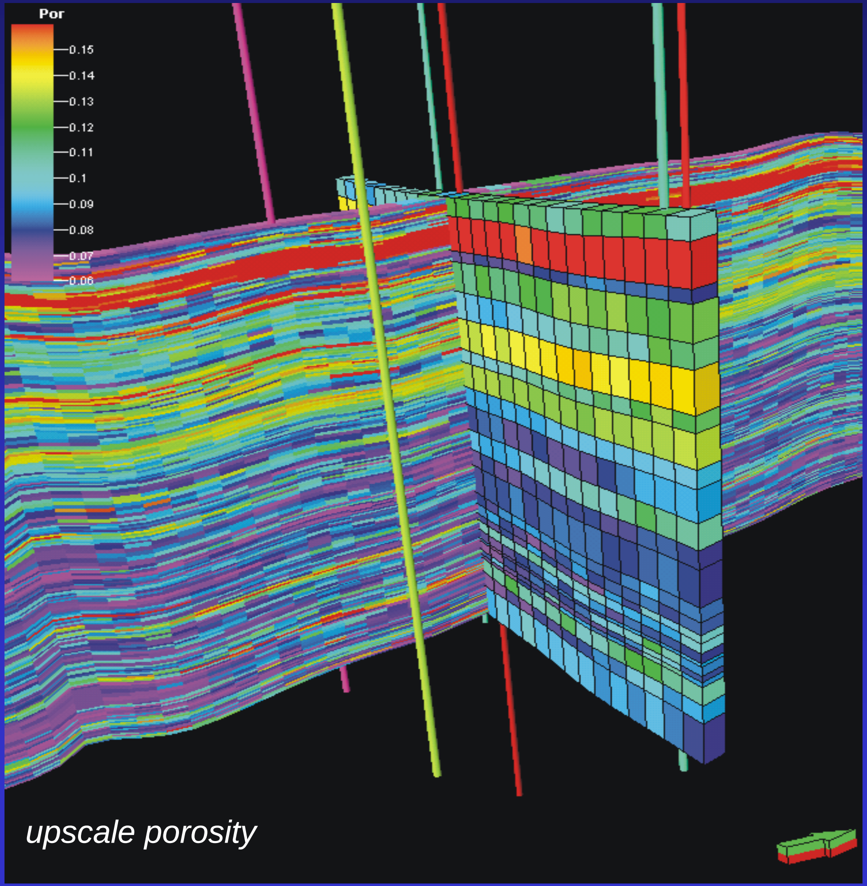


Midcontinent AAPG, Oklahoma City
September 13, 2005

Objectives of modeling project

Objective: Build 3D cellular model populated with lithofacies and petrophysical properties

Purpose:

1. Identify and quantify remaining gas in order to develop best field practices for efficient recovery.
2. Study sedimentary response to rapid glacio-eustatic sea level fluctuations on an extremely gently sloped ramp (shelf).

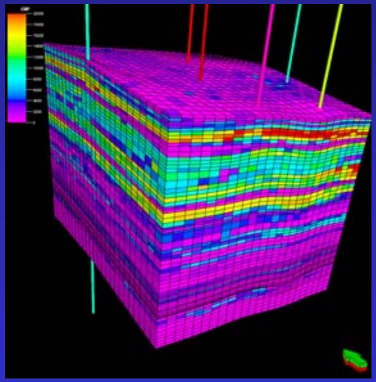
More specifically, and in conjunction with simulations studies

- Estimate original gas in place at well, region and field scales
- Reservoir connectivity at pore, flow unit, well, inter-well, region and field scales
- Differential depletion in stratigraphically separate reservoirs
- Production decline rates and EUR at ultra low pressures

Status and outline

Modeling project status:

- Township scale models have been built and tested by numerical simulation



- Components are in place for building field-wide cellular model and work is underway

To be covered today:

✓ Model workflow

✓ Major lithofacies and depositional model

✓ Large scale geometry of Hugoton and Panoma

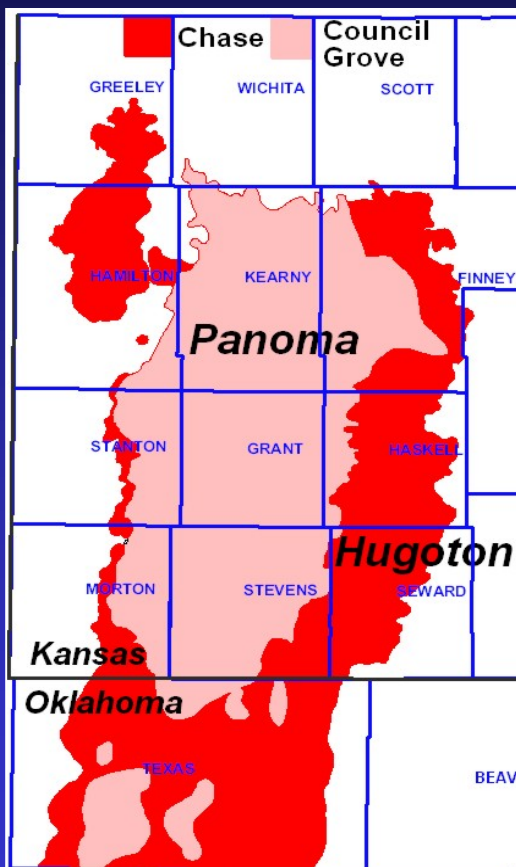
✓ Lithofacies in maps and cross sections

(Field 3D model not yet complete but plenty to see)

Hugoton and Panoma Stratigraphy

Thinly layered, alternating carbonate and siltstone reservoir in 13 marine-nonmarine sedimentary cycles

130 Miles

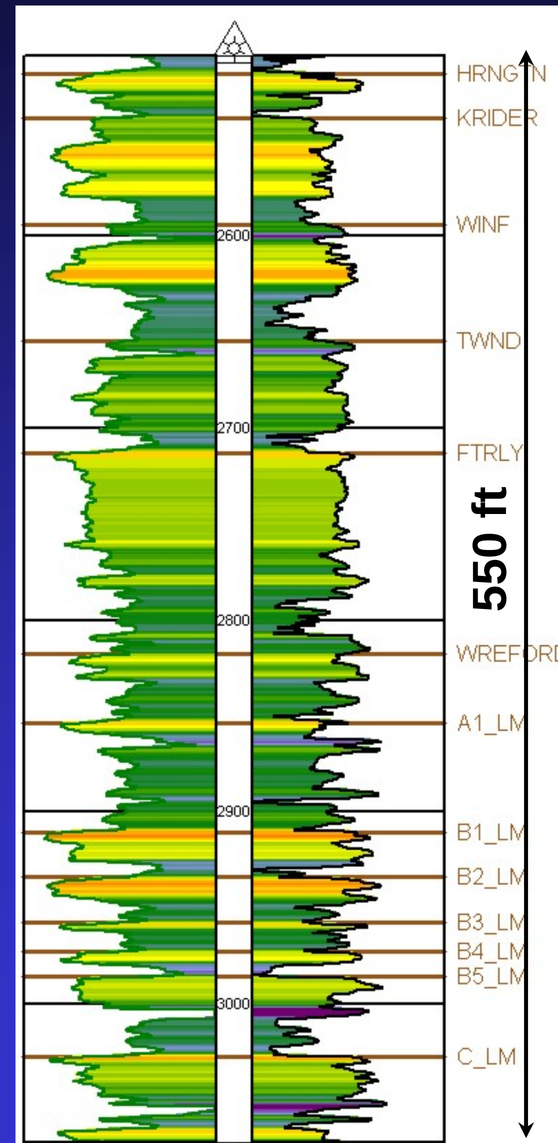


L. Permian

Wolfcampian

Chase Group (Hugoton)

Council Grove Gp. (Panoma)

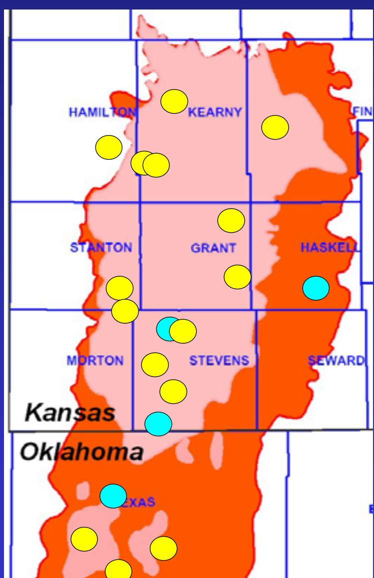


Herrington
Krider
Winfield
Towanda
Ft Riley
Florence
Wreford
Funston
Crouse
Middleburg
Eiss
Morrill
Cottonwood
Neva

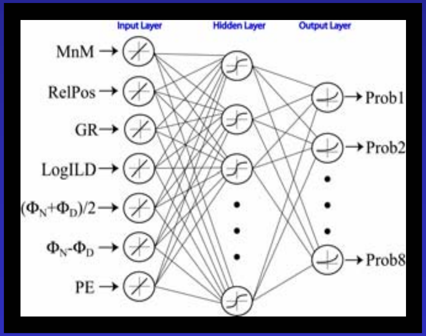
Geomodel Workflow (static model)

Gather data

CORE & ELog Var. → Neural Net → NODE WELLS → Stochastic Methods → 3D MODEL

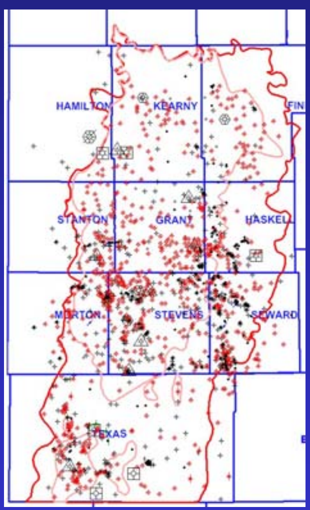


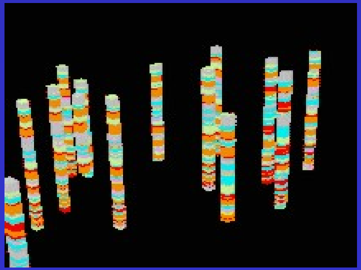
Lithofacies in core tied to log and geologic constraining variables

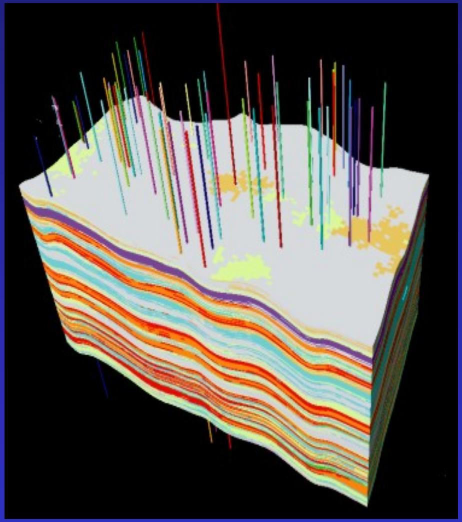


Train Neural network and predict lithofacies in non cored wells (nodes)

1400 "Node" Wells



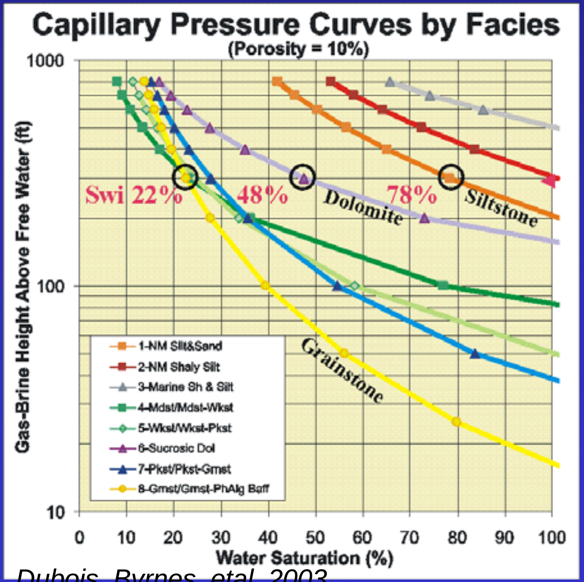




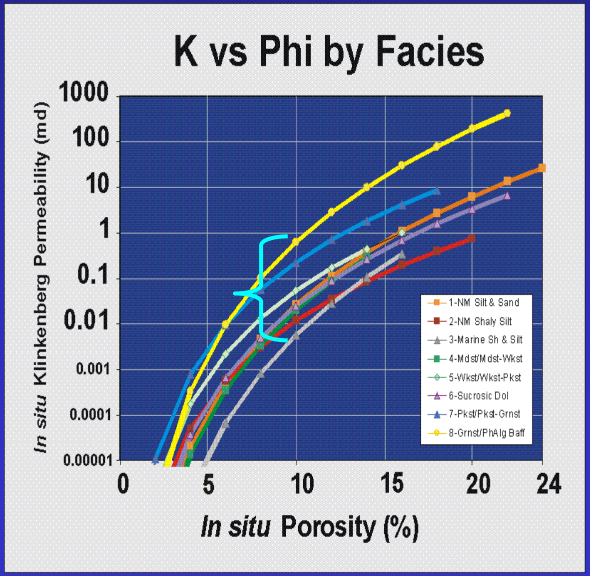
Fill volume between node wells using stochastic methods

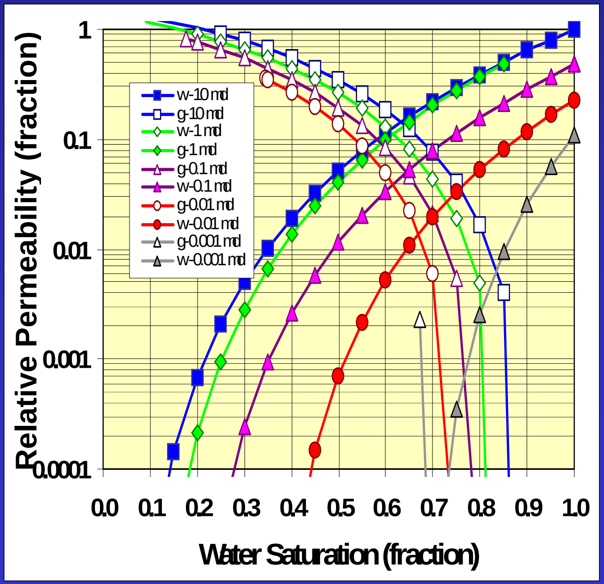
Develop dynamic model through empirical relationships

Model, Facies, Phi_{corr} → **Empirical Relations & Free Water Level** → Permeability, Water sat., Rel. Perm. → **Dynamic Model & Simulation** → Differential Pressure, Corrected MatBal OGIP

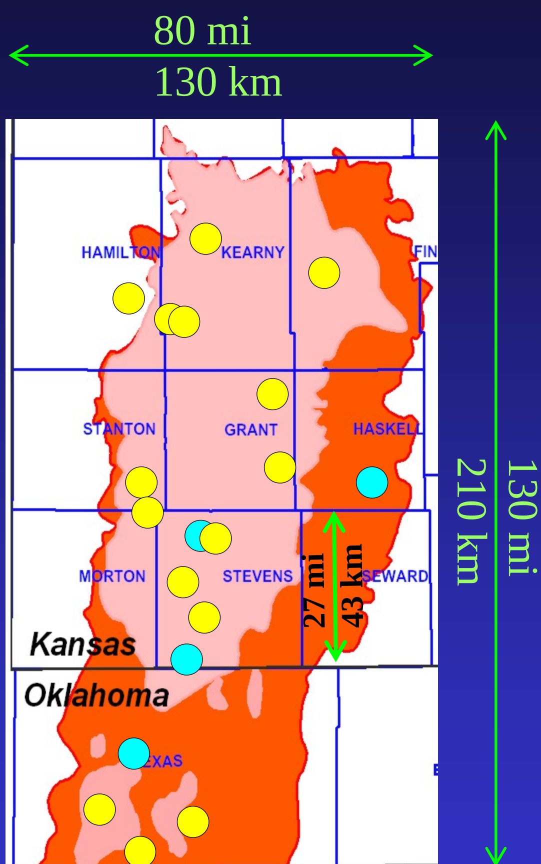


Dubois, Byrnes etal, 2003





Lithofacies from Core to “Node” Wells



Current training set
Other

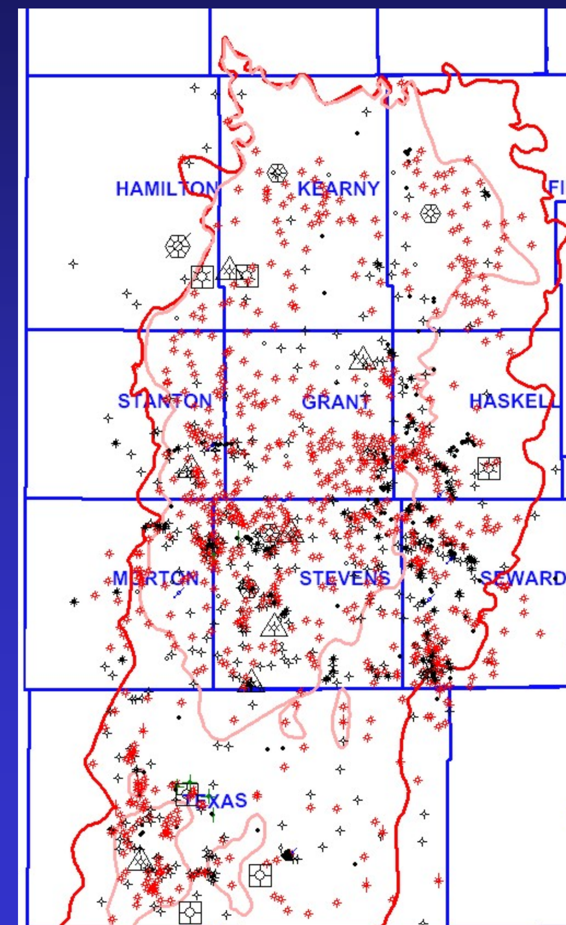
Some wells have both Chase and Council Grove core

Training set for neural network lithofacies prediction

Well count	1/2 foot intervals	
8	3952	Chase
10	4593	Council Grove

8545 ½-foot intervals with lithofacies tied to log and core properties

Lithofacies predicted at 1369 “node wells”



Neural Network Training and Predictions

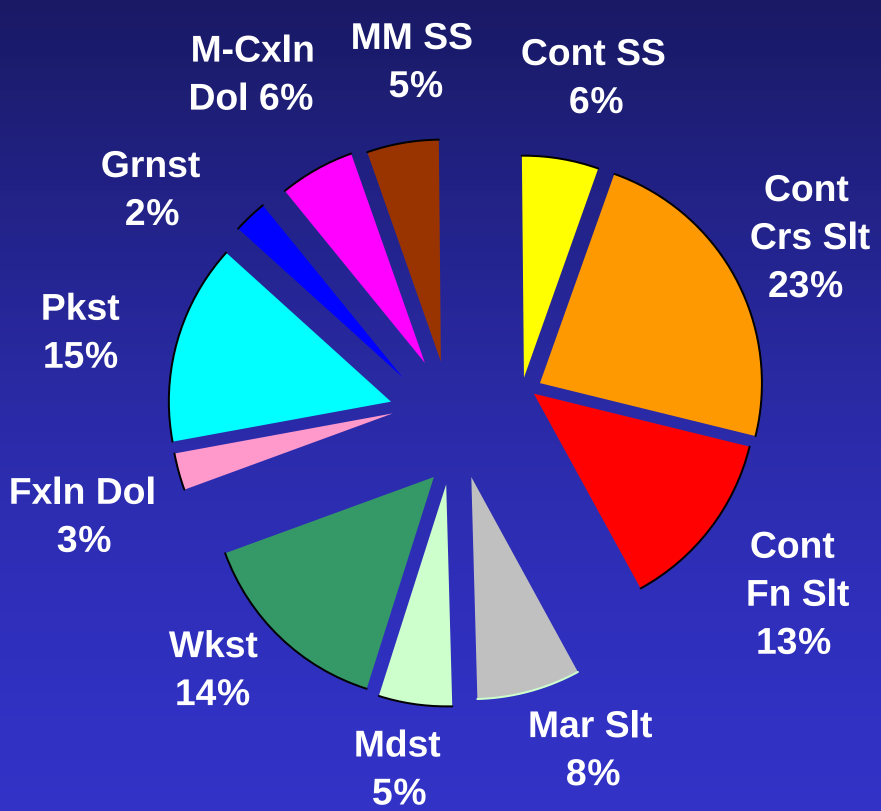
Lithofacies in training set and predicted in wells

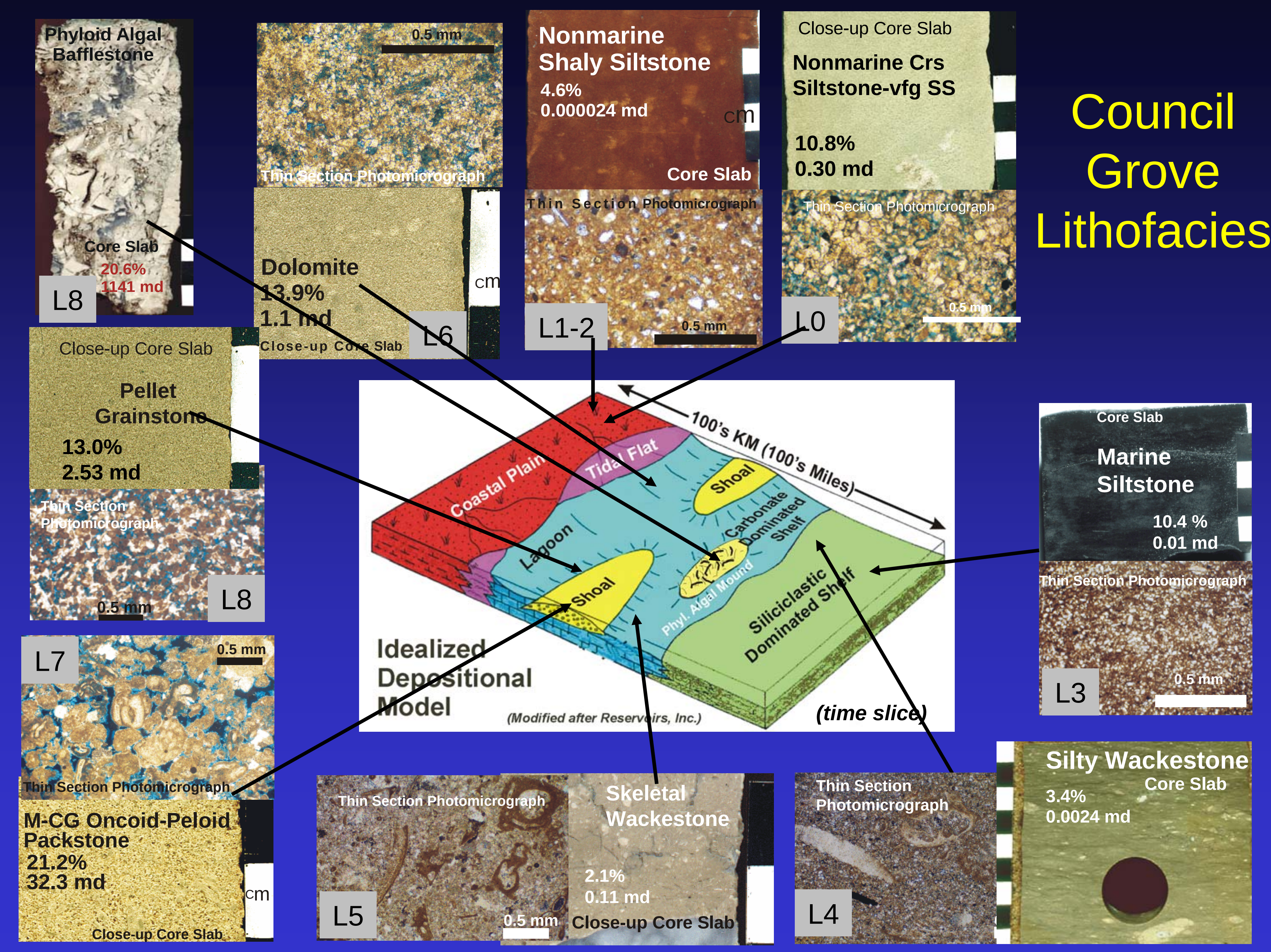
Facies	Council Grove	Chase	All (Train)	1369 Wells Predicted (Predict)	Training	Predicted
Continental						
Sandstone	8%	4%	6%	2%		
Coarse Silt	28%	23%	23%	20%		
Fine Silt	24%	4%	13%	8%	**42%**	**30%**
Marine						
Siltstone	9%	7%	8%	10%		
Carb Mdst	7%	5%	5%	4%		
Wackestone	18%	13%	14%	19%	**27%**	**33%**
Fxln Dol.	4%	2%	3%	4%		
Packstone	15%	17%	15%	23%		
Grainstone	4%	1%	2%	0%		
M-Cxln Dol.	0%*	12%	6%	4%		
Sandstone	0%**	12%	5%	6%	**31%**	**37%**

** Insufficient training sample. Combined with Fxln Dolomite*
*** Insufficient training sample. Combined with Siltstone.*

Distribution of lithofacies predicted in 1369 wells is similar to that in training set.

Distribution of eleven lithofacies in training set

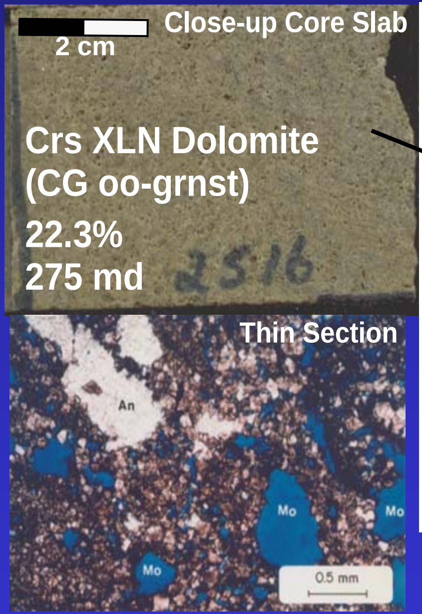


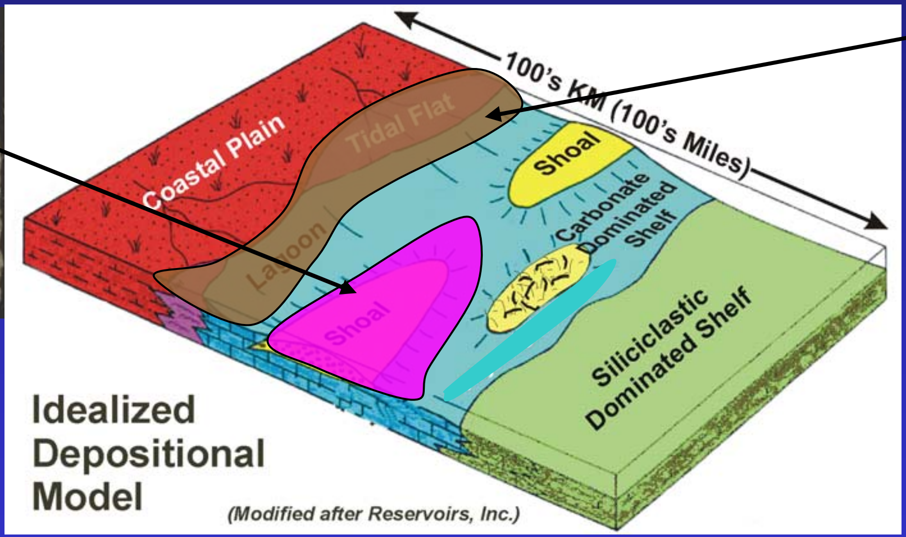


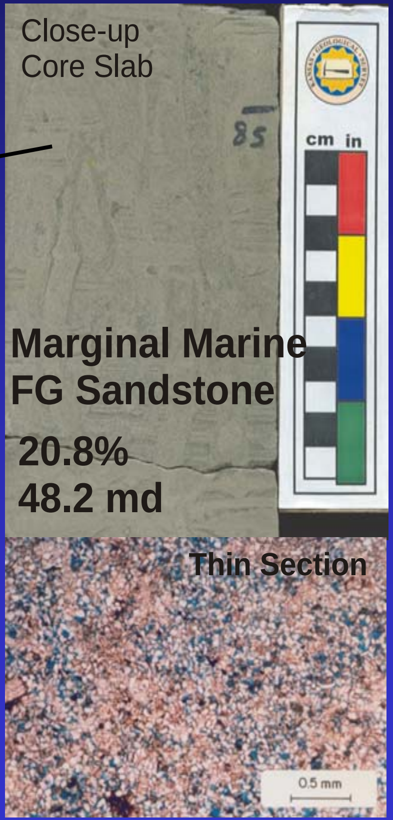
Council Grove Lithofacies
Phyloid Algal Bafflestone
Core Slab
20.6%
1141 md
L8
0.5 mm
Thin Section Photomicrograph
Dolomite
13.9%
1.1 md
Close-up Core Slab
cm
L6
Nonmarine Shaly Siltstone
4.6%
0.000024 md
cm
Core Slab
Thin Section Photomicrograph
0.5 mm
L1-2
Close-up Core Slab
Nonmarine Crs Siltstone-vfg SS
10.8%
0.30 md
Thin Section Photomicrograph
0.5 mm
L0
Close-up Core Slab
Pellet Grainstone
13.0%
2.53 md
Thin Section Photomicrograph
0.5 mm
L8
Core Slab
Marine Siltstone
10.4 %
0.01 md
Thin Section Photomicrograph
0.5 mm
L3
100's KM (100's Miles)
Coastal Plain
Tidal Flat
Shoal
Carbonate Dominated Shelf
Lagoon
Shoal
Phyl. Algal Mound
Siliciclastic Dominated Shelf
Idealized Depositional Model
(Modified after Reservoirs, Inc.)
(time slice)
L7
0.5 mm
Thin Section Photomicrograph
M-CG Oncoid-Peloid Packstone
21.2%
32.3 md
cm
Close-up Core Slab
Thin Section Photomicrograph
0.5 mm
L5
Skeletal Wackestone
2.1%
0.11 md
Close-up Core Slab
Thin Section Photomicrograph
L4
Silty Wackestone
Core Slab
3.4%
0.0024 md

Unique Chase Lithofacies

Two additional lithofacies plus same nine as in Council Grove but in different proportions. No phylloid algal facies.

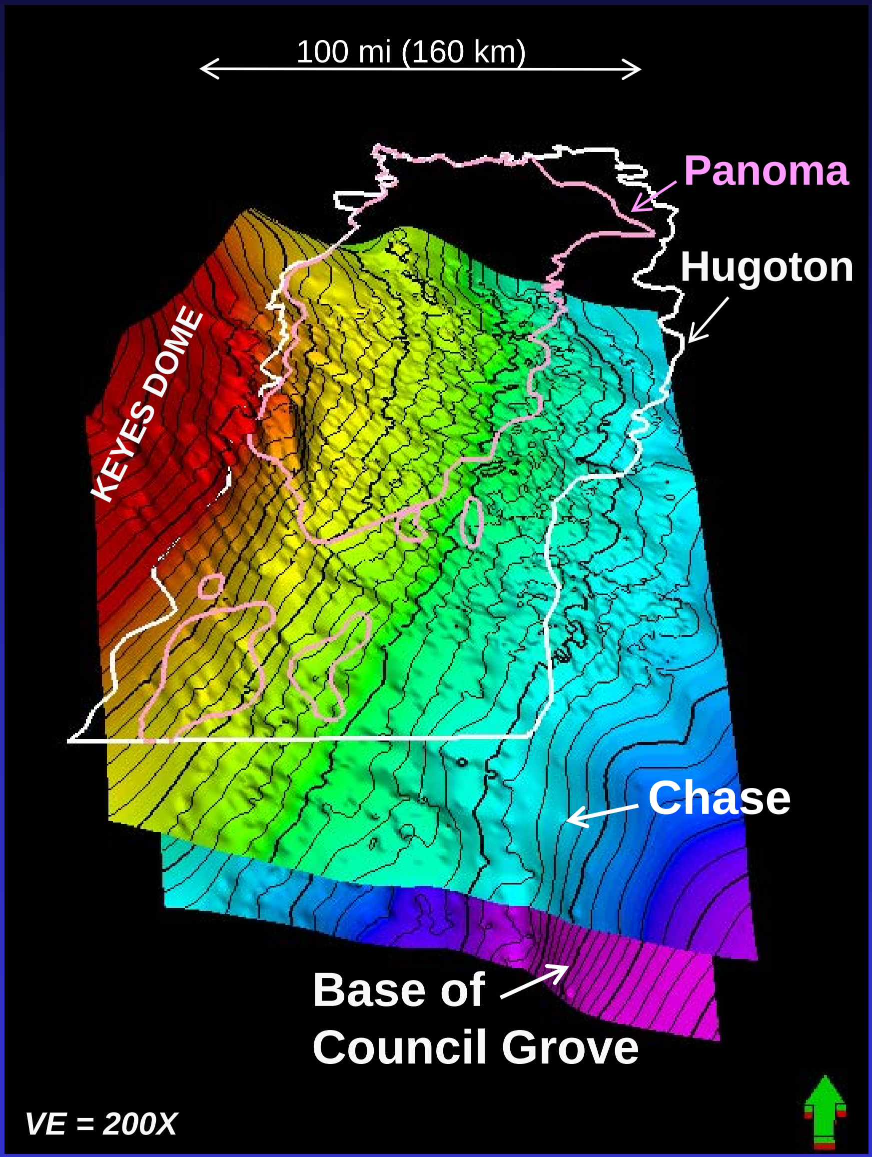




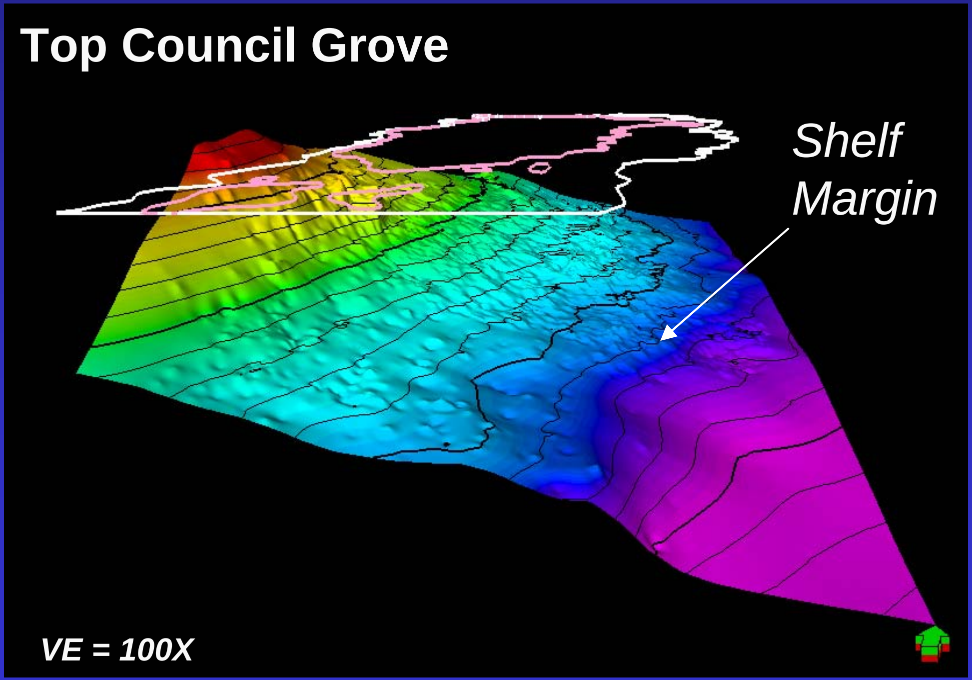


Dolomitized medium to coarse-grained ooid and bioclastic grainstone are the dominant reservoir facies in Chase

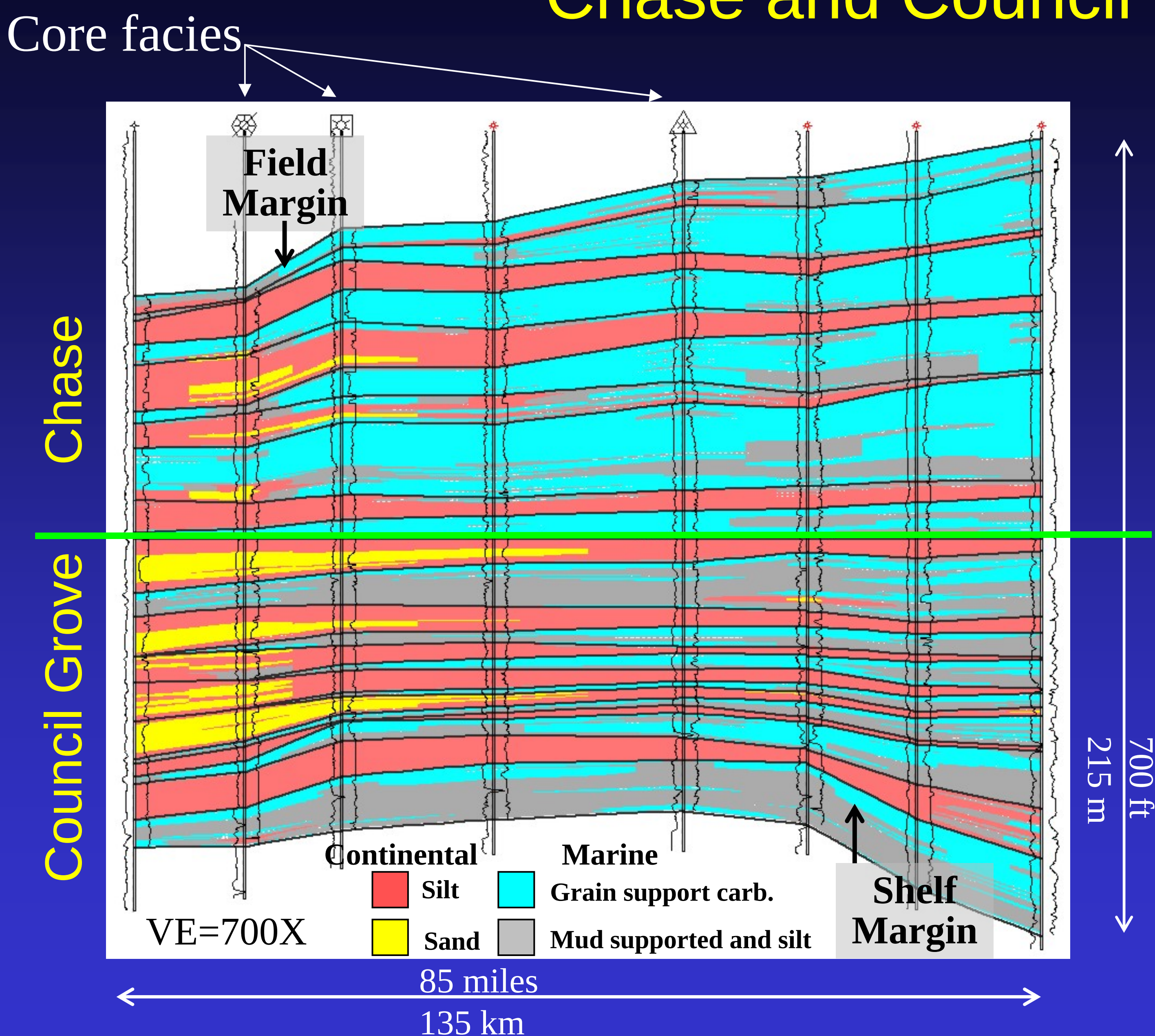
Present Day Structure

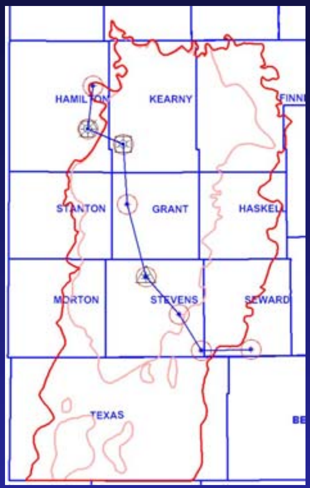


Reservoirs of Hugoton and Panoma Fields were deposited on a very gently dipping shelf. Relief was much less than it is today.



Chase and Council Grove





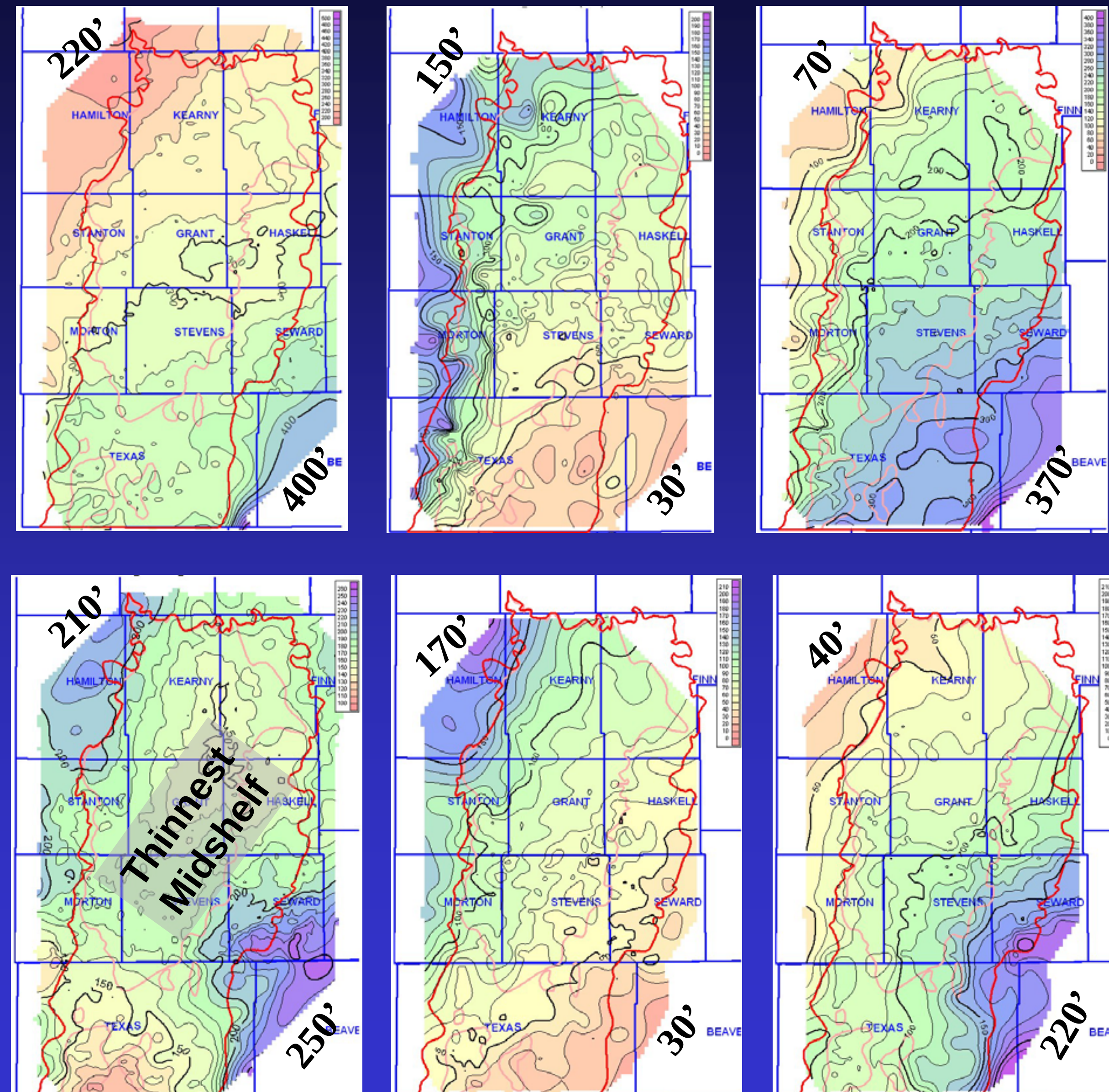
- ✓ Carbonate thins toward updip field margin
- ✓ Redbeds thin basinward
- ✓ Eolian sands at west margin
- ✓ Council Grove thinnest at mid-shelf

Similar sedimentation patterns in Chase and Council Grove

Gross interval | Net “Continental” | Net Marine

Chase

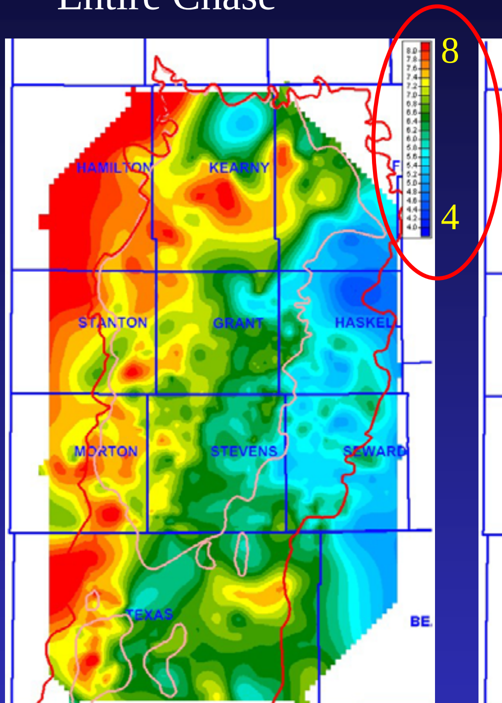
Council Grove (thru B5_LM)



Series of slides based on facies predicted by Nnet in 1369 wells

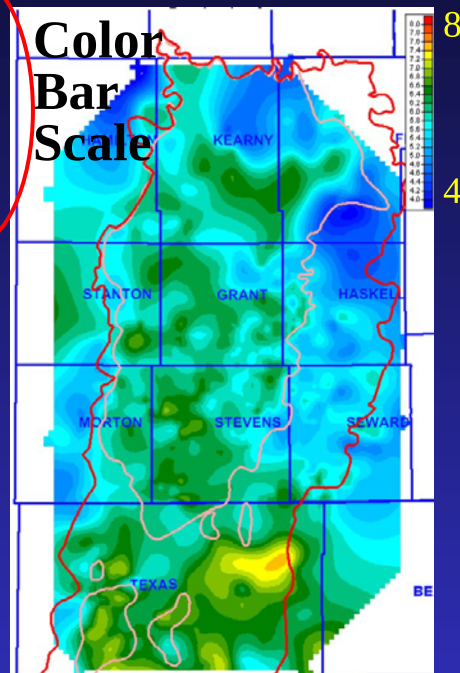
Mean Lithofacies in Marine Intervals

Entire Chase



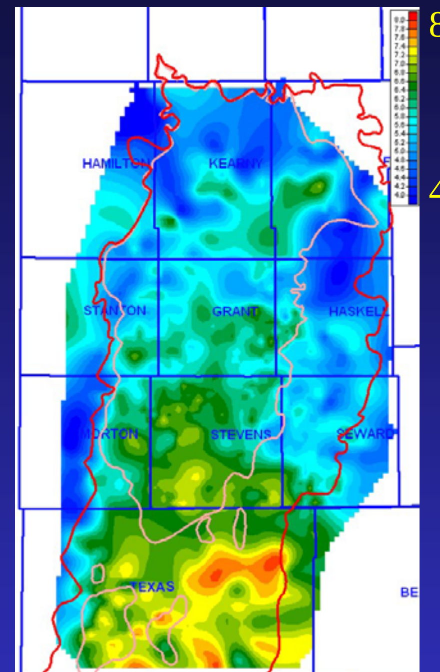
Facies 3-10
Mean F = 6.7 SD = 0.9
F10 dominates west margin

Entire Chase



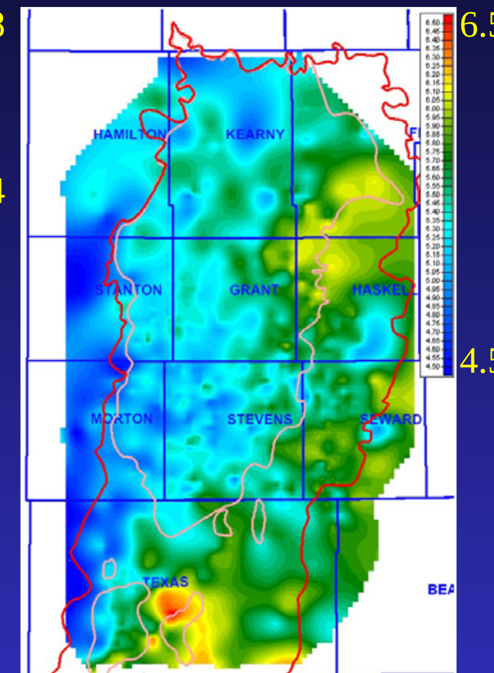
Facies 3-9
Mean = 5.8 SD = 0.6

Chase to Ft Riley



Facies 3-9
Mean = 5.8 SD = 0.9
F9 dominates south

Council Grove to C_SH



Facies 3-9
Mean = 5.4 SD = 0.4
F6 dominates to NE
F7 dominates to SE

5.8 →
6.7 →

Marine
- 3 Siltstone
- 4 Carb Mdst
- 5 Wackestone
- 6 Fxln Dol.
- 7 Packstone
- 8 Grainstone
- 9 M-Cxln Dol.
- 10 Sandstone

Continental
- 0 Sandstone
- 1 Coarse Silt
- 2 Fine Silt

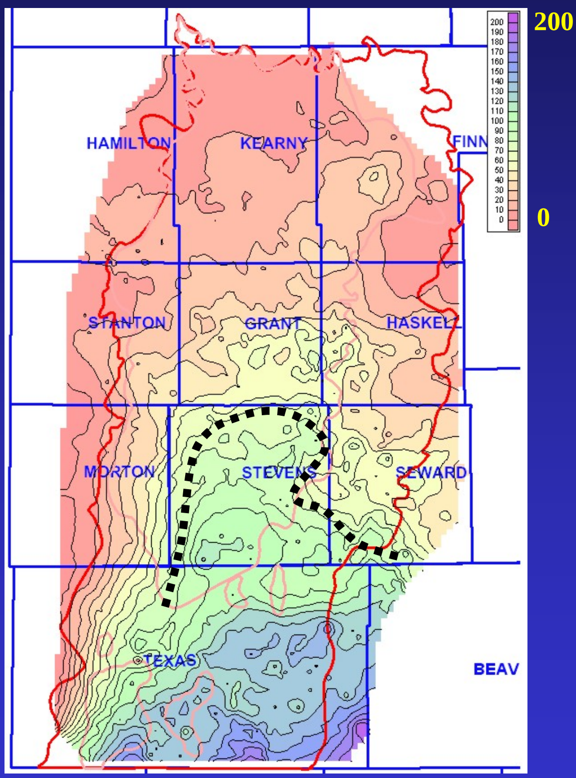
Shown are the mean code value for lithofacies predicted by neural network models in 1350 wells

Main “Pay” Lithofacies in Chase (F7-9)

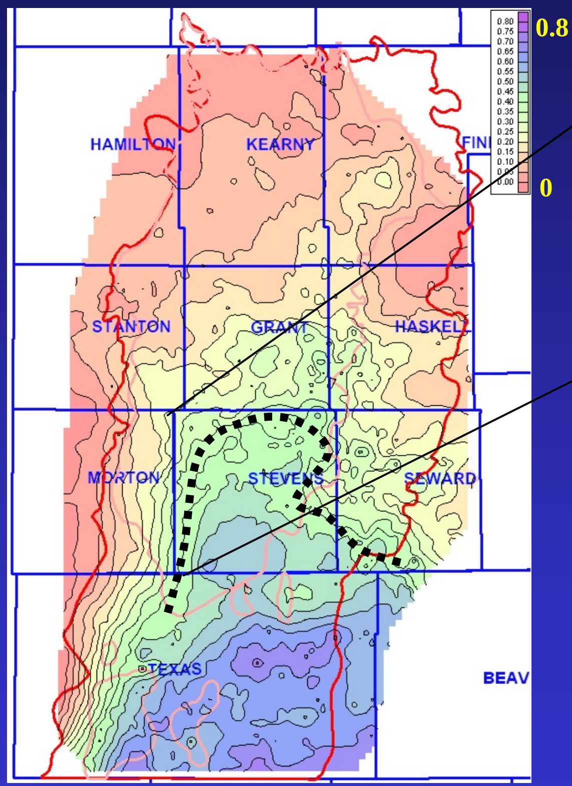
Herrington
Krider
Winfield
Towanda

(Herrington through Gage)

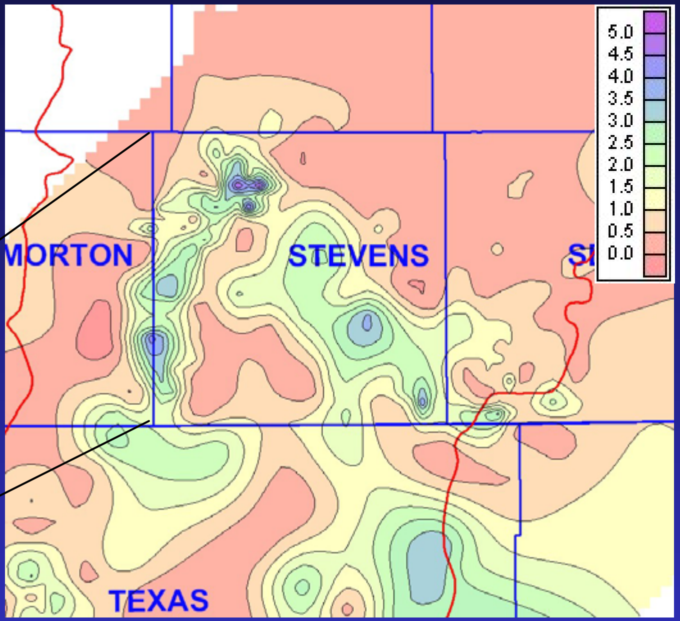
Krider only PhiH for F9



Net thickness
Facies 7 thru 9



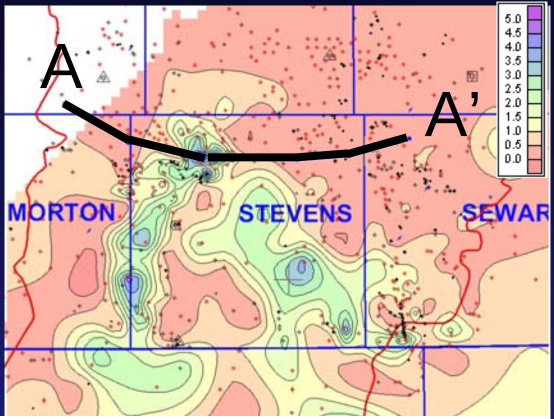
Net / Gross
Facies 7 thru 9



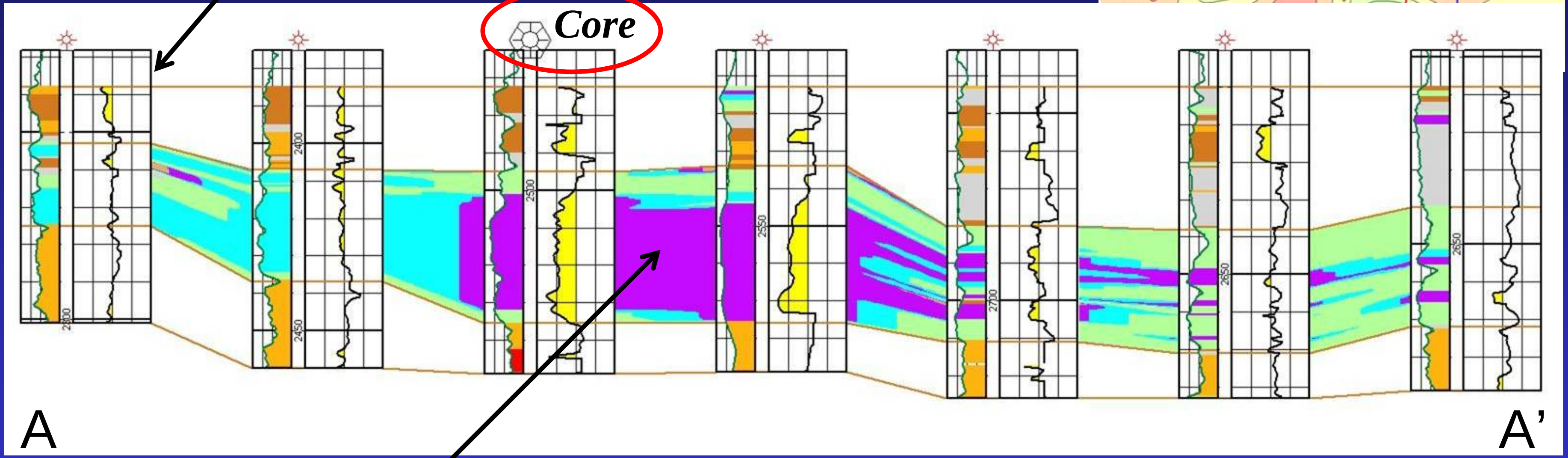
Phi x H for Facies 9
Cutoff phi >15%

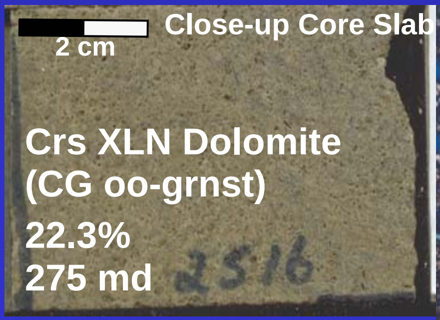
Accumulation of coarse-grained bioclastic-ooid sand associated with bathymetry of embayment *near* the shelf margin

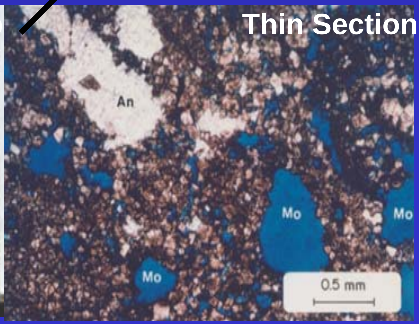
Krider Ooid shoal facies in Stevens County



10 foot divisions

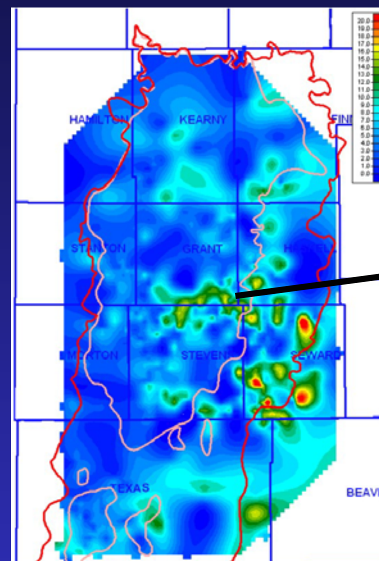




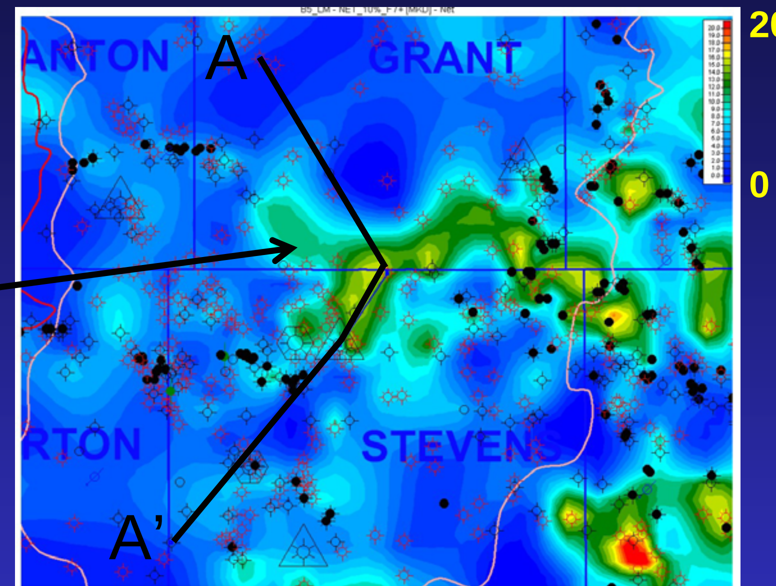


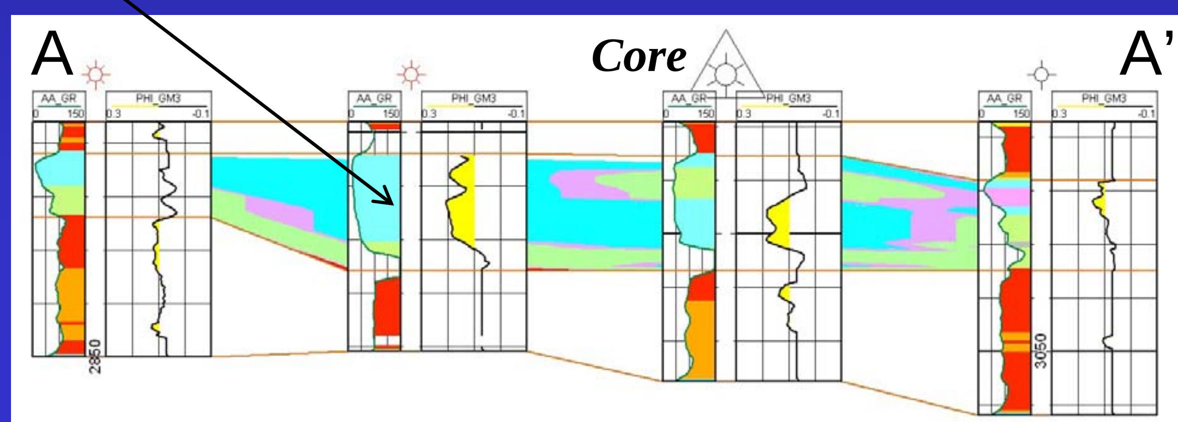
1	Coarse Silt	
3	Siltstone	
4-5	Mdst-Wackestone	
7	Pack-Grainstone	
9	M-Cxln Dol.	
10	Sandstone	

Cottonwood (B5_LM) Phylloid Algal Mounds



Net H, F7-8, Phi >10%

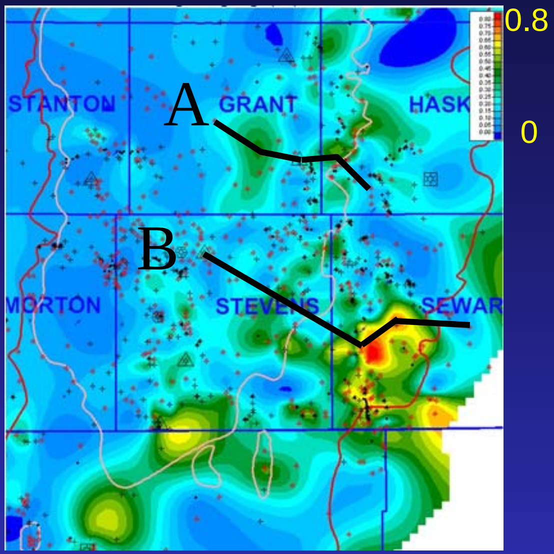




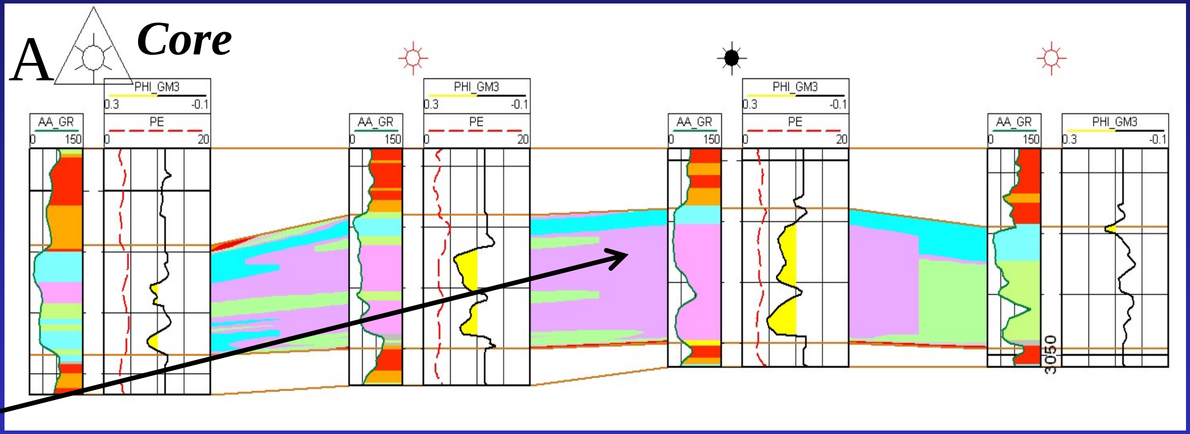
- 0 Sandstone
- 1 Coarse Silt
- 2 Fine Silt
- 3 Siltstone
- 4-5 Mdst-Wackestone
- 6 Fxln Dol.
- 7-8 Pack-Grainstone

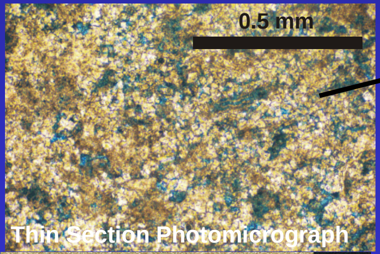
Crouse (B1_LM) fine-crystalline dolomite lithofacies

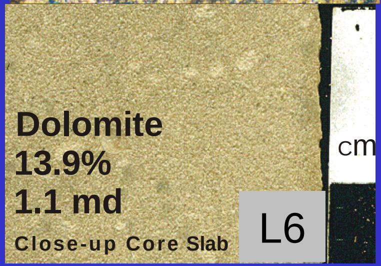
F6-8, phi > 8%, Net/Gross

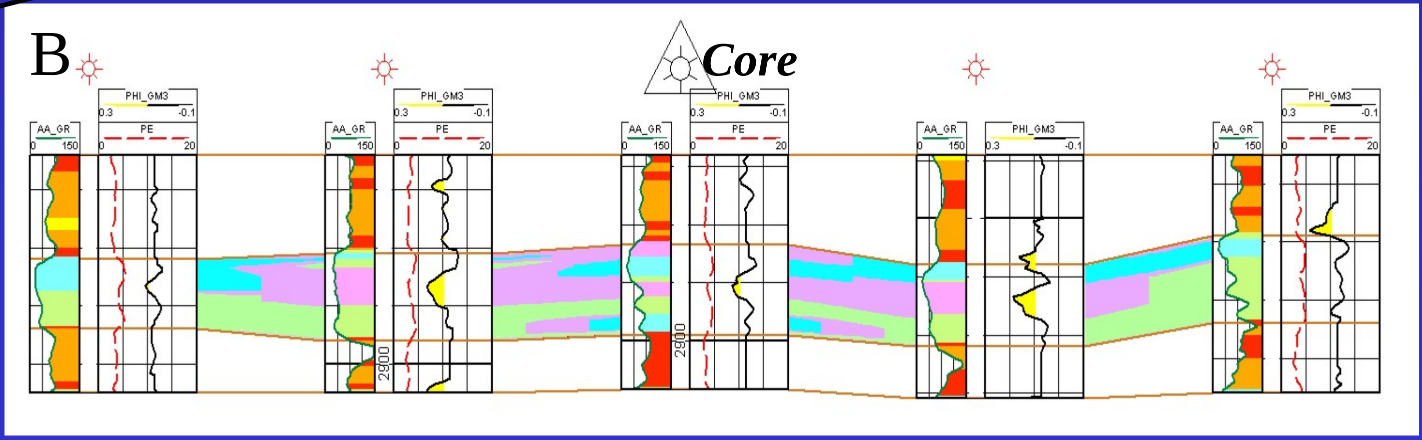


- 0 Sandstone
- 1 Coarse Silt
- 2 Fine Silt
- 3 Siltstone
- 4-5 Mdst-Wackestone
- 6 Fxln Dol.
- 7-8 Pack-Grainstone







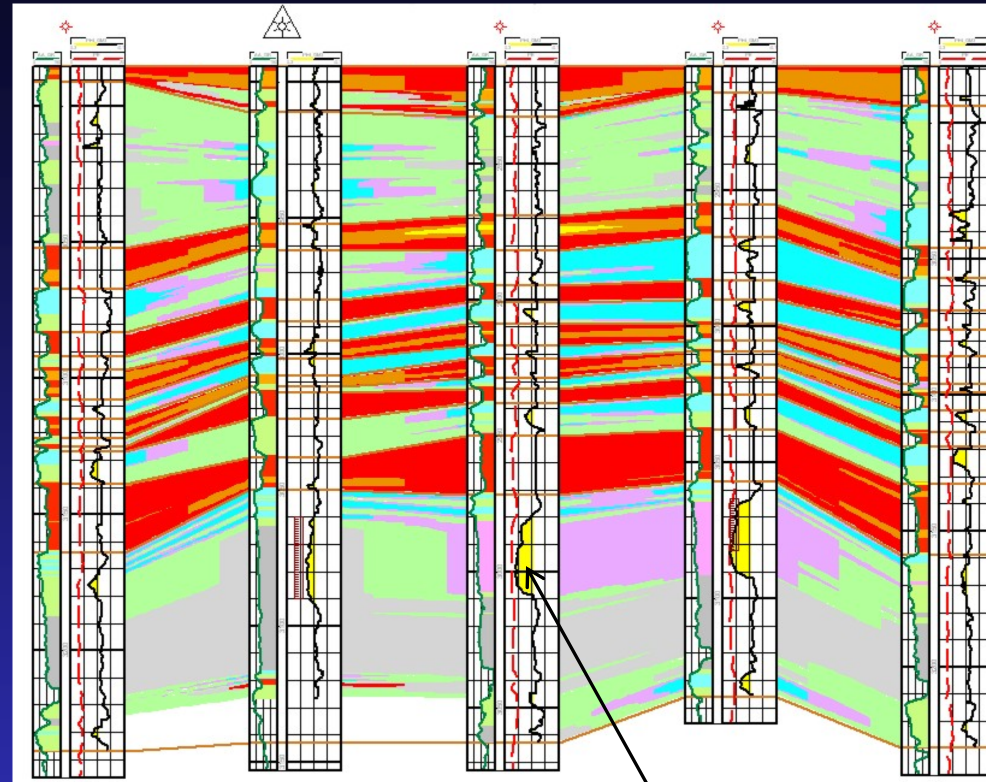


Neva (C_LM)

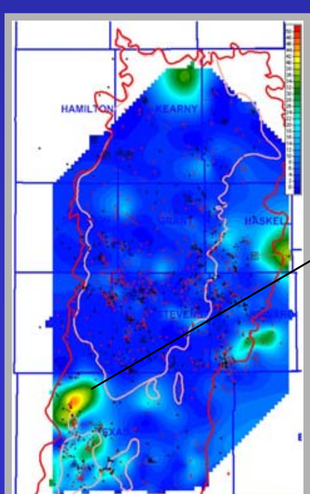
- 0 Sandstone
- 1 Coarse Silt
- 2 Fine Silt
- 3 Siltstone & Sandstone
- 4-5 Mdst-Wackestone
- 6 Fxln Dol.
- 7-8 Pack-Grainstone

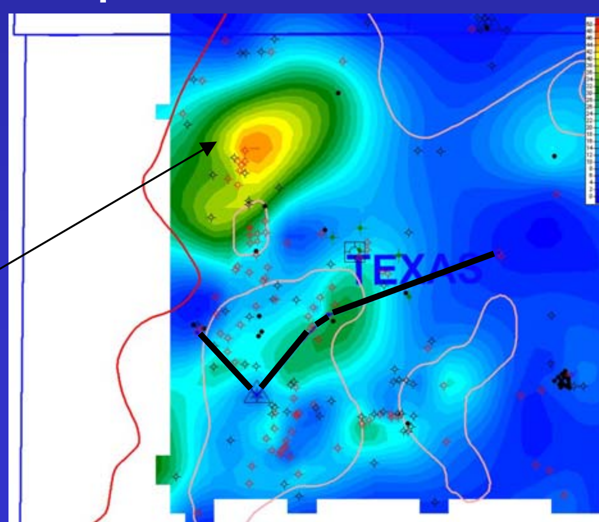
Top Council Grove

Neva



Net thickness, phi >15%

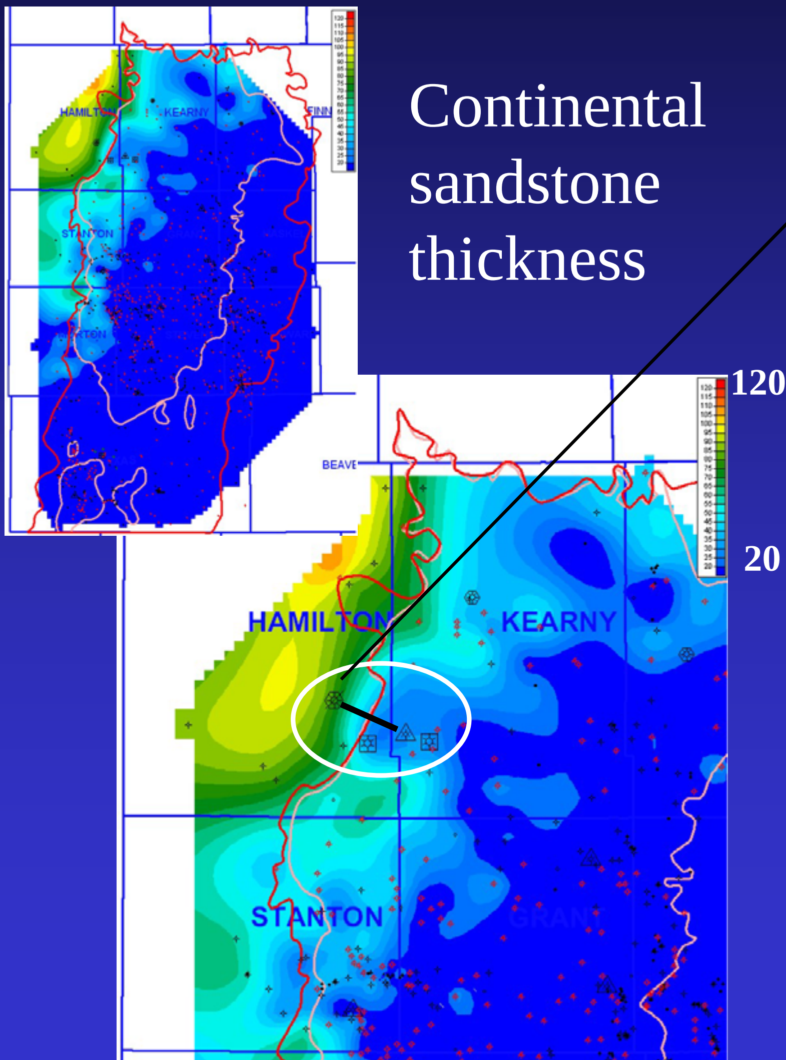


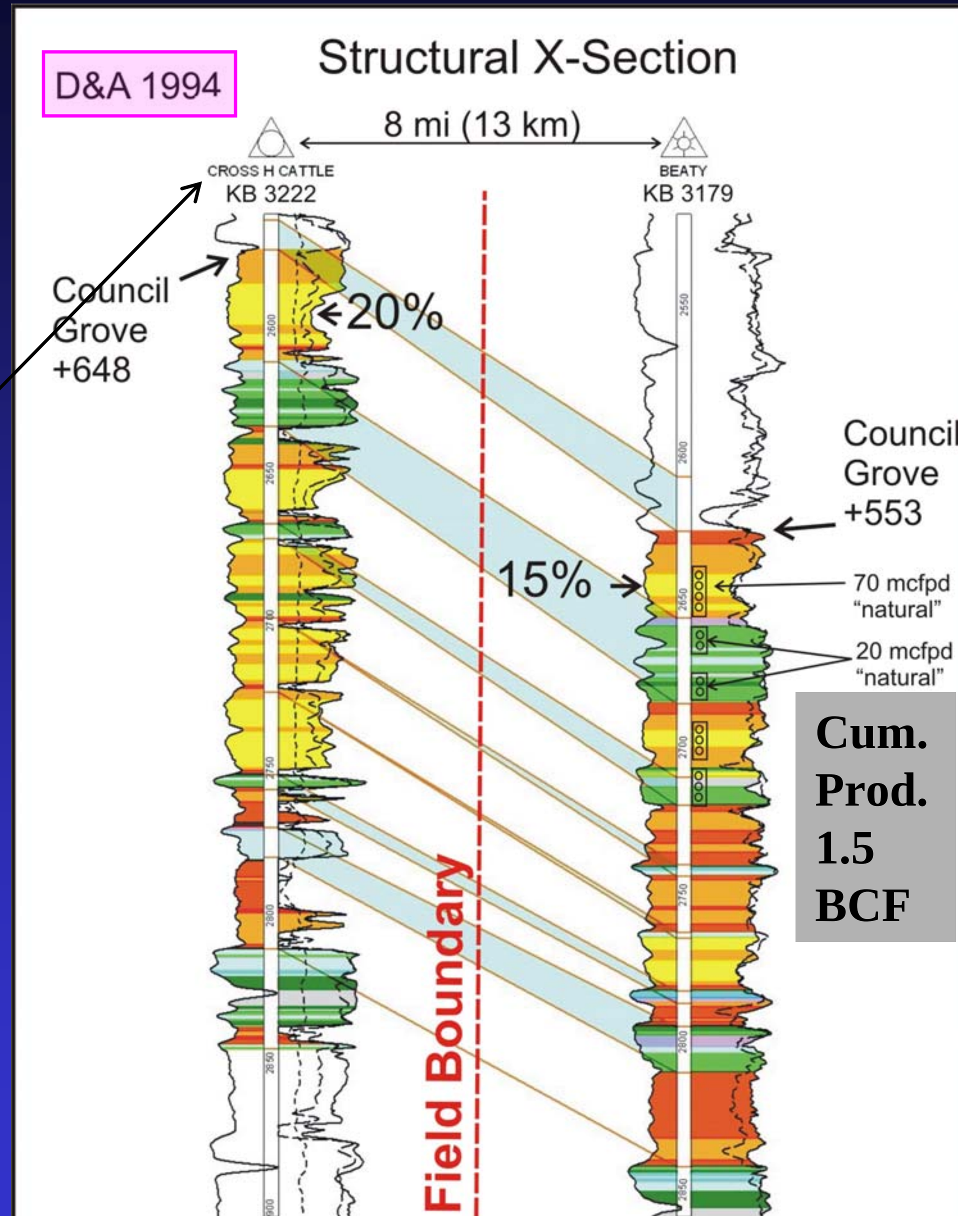


Fine-grained sandstone in lower Council Grove is pay in Texas County

Eolian sandstone Council Grove

Continental sandstone thickness





Dubois and Goldstein, 2005

Summary

- Township scale models have been built and tested by numerical simulation
- Components are in place for building field-wide cellular model (underway)
- Neural network models are proving effective in facies predictions and building an accurate geomodel
- We anticipate being able to successfully delineate remaining gas in place in the Hugoton and Panoma Fields

Acknowledgements

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Anadarko Petroleum Corporation
BP America Production Company
Cimarex Energy Co.
ConocoPhillips Company
E.O.G. Resources Inc.
Medicine Bow Energy Corporation
Osborn Heirs Company
OXY USA, Inc.
Pioneer Natural Resources USA, Inc.

also geoPlus (Petra) and Schlumberger (Petrel)