Distribution, Thickness, Reservoir Properties, and Production Characteristics of the Tonkawa Sandstone in Northwestern Roger Mills and Southwestern Ellis Counties, Oklahoma*

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Abstract

The Tonkawa Sandstone is an important horizontal drilling objective on the northern shelf of the Anadarko Basin. Cores of the Tonkawa interval from the Bishop and Northwest Crawford fields were integrated with wireline-log and production data to identify depositional features, interpret the depositional setting and environments, and determine rock properties and reservoir characteristics. The lithofacies, current-induced structures and biogenic features observed in core, mapped distribution patterns, and sandstone geometry from wireline logs support the interpretation that the Tonkawa Sandstone in the study area represents a prograding deltaic complex. Observed depositional facies include distributary channel, distributary mouth bar, distal bar, prodelta, interdistributary bay, and crevasse splay deposits. The distribution and apparent reworking of sandstone bodies are indicative of a fluvial-dominated system influenced by destructive marine processes. Thickness maps of genetic units revealed shifting of the primary depocenters in response to available accommodation. The sandstone is dominantly very fine-grained sublitharenite that is glauconitic. Primary porosity is almost totally occluded by syntaxial quartz overgrowths and pore-filling calcite cement. Secondary porosity is the principal type and consists of partially dissolved grains, grain molds, oversized pores, and elongate pores. Porosity and permeability measurements indicate a range in porosity of 3.7 to 15.4 percent, whereas permeability ranges from 0.16 to 4.86 millidarcies. Porosity and permeability display a positive linear relationship to each other. Net-sandstone thickness, porosity, and depositional facies are strongly linked to cumulative production volumes of oil and gas from Tonkawa Sandstone reservoirs.

Selected References

Brown, L.F., 1979, Deltaic sandstone facies of the Mid-Continent; *in* N.J. Hyne, N.J., Pennsylvanian Sandstones of the Mid- Continent: Tulsa Geological Society Special Publication no.1, p.35-63.

Bush, D.A, 1971; Genetic Units in delta prospecting: AAPG Bulletin, v. 55/9, p. 1137-1154.
Coleman, J.M., and D.B. Prior, 1980, Deltaic Sand Bodies: AAPG Education Course Note Series no. 15, p. 171.

Fies, M.W., 1988, Depositional environments and diagenesis of Tonkawa formation (Virgilian) in Woods and parts of Woodward counties, Oklahoma: Oklahoma State University unpublished M.S. thesis.

Folk, R.L., 1968; Petrology of Sedimentary Rocks; Hemphill books, Austin, Texas, 170 p.

Gibbons, K.E., 1964, Pennsylvanian of the north flank of the Anadarko Basin: Oklahoma CityGeological Society Shale Shaker, v. 12/5, p. 2-19.

Johnson, K.S., 1988, Geologic evolution of the Anadarko Basin: Anadarko Basin Symposium, 1988: Oklahoma Geological Survey Circular 90, 289 p. 3-12.

Kolb, C.., and J.R. Van Lopik, 1958, Geology of the Mississippi River Deltaic Plain, Southern Louisiana: Technical Report no. 3-483, U.S. Army Engineer Waterways Experiment Station, Vicksburg MS, 120 p. .

Kumar, N., and R.M. Slatt, 1984, Submarine-fan and slope facies of Tonkawa (Missourian-Virgilian) Sandstone in deep Anadarko Basin: AAPG Bulletin, v. 68/12, p. 1834-1856.

Padgett, P.C.O., 1988, Petrology, diagenesis, and deposition environment of the Tonkawa Sandstone in southwestern Dewy County: Oklahoma; Oklahoma State University unpublished M.S. thesis, 87 p.

Pate, J.D., 1959, Stratigraphic traps along the north shelf of the Anadarko Basin, Oklahoma: AAPG Bulletin, v. 34, p. 39-59.

Slate, H.L., 1964, Petroleum geology of the Taloga-Custer City area, Dewey and Custer counties, Oklahoma: The Shale Shaker Digest IV, v. XII-XIV, p. 184-198.

Wiggers, C.L., 2004, Distribution, depositional environment, and reservoir properties of the Pennsylvanian Tonkawa Sandstone in South Peek Field, Ellis and Roger Mills counties, Oklahoma: The Shale Shaker Digest p. 1-21.

DISTRIBUTION, THICKNESS, RESERVOIR PROPERTIES, AND PRODUCTION CHARACTERISTICS OF THE TONKAWA SANDSTONE IN NORTHWESTERN ROGER MILLS AND SOUTHWESTERN ELLIS COUNTIES, OKLAHOMA

Anadarko Basin

By: Alex Fitzjarrald[1] and Jim Puckette[2]

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Purpose and Methodology

Purpose

- Examine the sedimentary structures, distribution, and geometry of the Tonkawa Sandstone to determine depositional environments
- Analyze the effects of diagenesis on porosity and permeability of the Tonkawa Sandstone
- Determine how geologic characteristics influence production from the Tonkawa Sandstone reservoirs

Method

- Data were collected from wireline logs, core and thin section examination, x-ray diffraction, and conventional core plug porosity/permeability measurements.
- Data were integrated to construct maps, cross sections, graphs, and tables necessary to determine reservoir characteristics and link these to oil- and gas-production volumes.

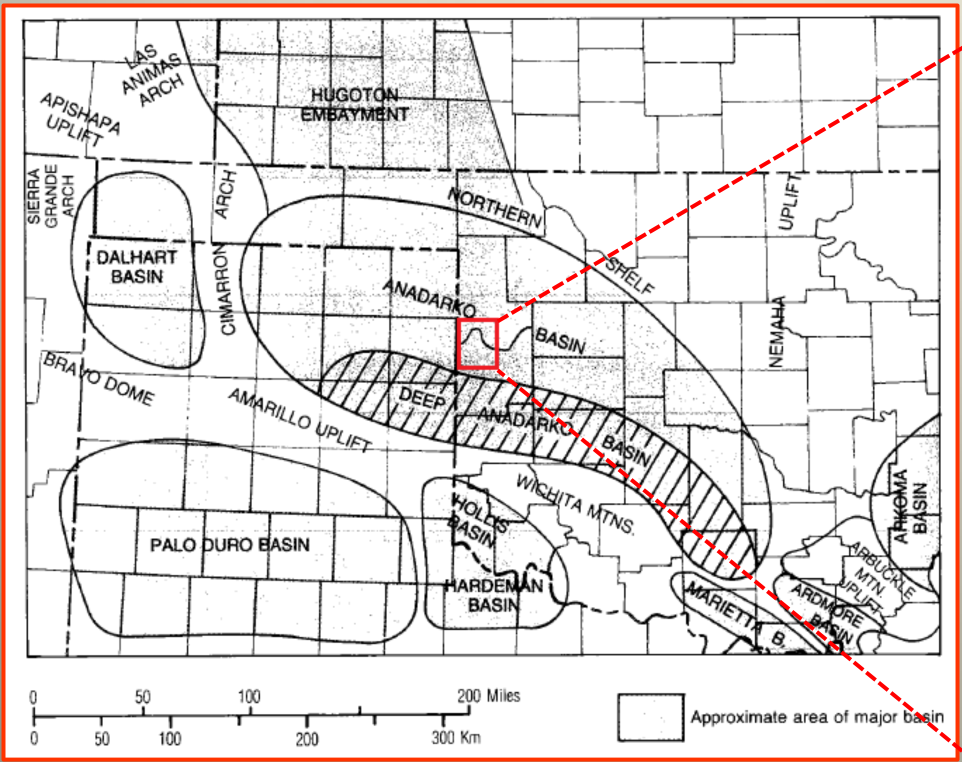
Contents

- Introduction
  - Study Area
  - Geologic Setting
- Depositional Environment
  - Sedimentary structures
  - Geometry of sandstones
  - Distribution
- Petrographic Analysis
- Reservoir Quality
- Production Characteristics
- Conclusions

Introduction

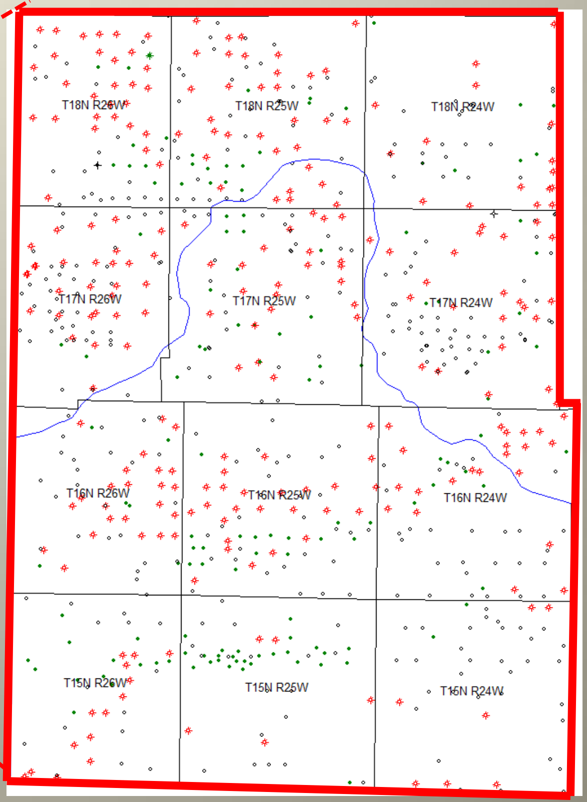
Study Area: Ellis and Roger Mills Counties

Anadarko Basin



(Johnson, 1988)

Area of Interest



(T.15N. – 18N.; R.24W. – 26W.)

Geologic Setting

Stratigraphic Nomenclature

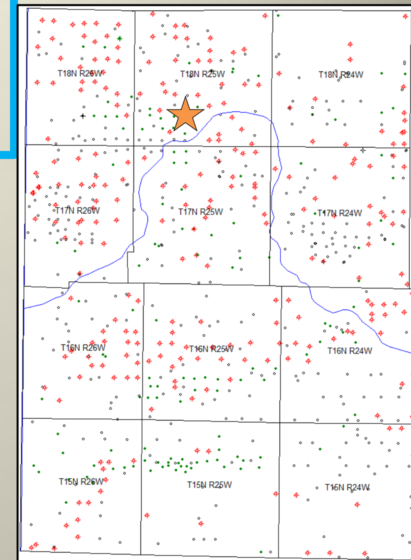
SYS.	SUB SYS.	SERIES	GROUP	UNIT
CARBONIFEROUS	PENNSYLVANIAN	VIRGILIAN	Shawnee/Cisco	Topeka Ls Pawhuska Ls Hoover Ss Elgin Ss Oread Ls Heebner Sh Endicott Ss
			Douglas/Cisco	Lovell Ls Haskell Ls **Tonkawa Ss**
		MISSOURIAN	Lansing/Hoxbar	Avant Ls Cottage Grove Ss
			Kansas City/Hoxbar	Dewey Ls Hogshooter Ls Layton Ss Checkerboard Ls **Cleveland Ss**
		DESMOINESIAN	Marmaton	Big Lime Oswego
			Cherokee	Cherokee Marker Prue Ss Verdigris Ls Skinner Ss Pink Ls **Red Fork Ss** Inola Ls Mona
		ATOKAN	Atoka	**Atoka** 13 Finger Ls
		MORROWAN	Morrow	**Morrow** Primrose

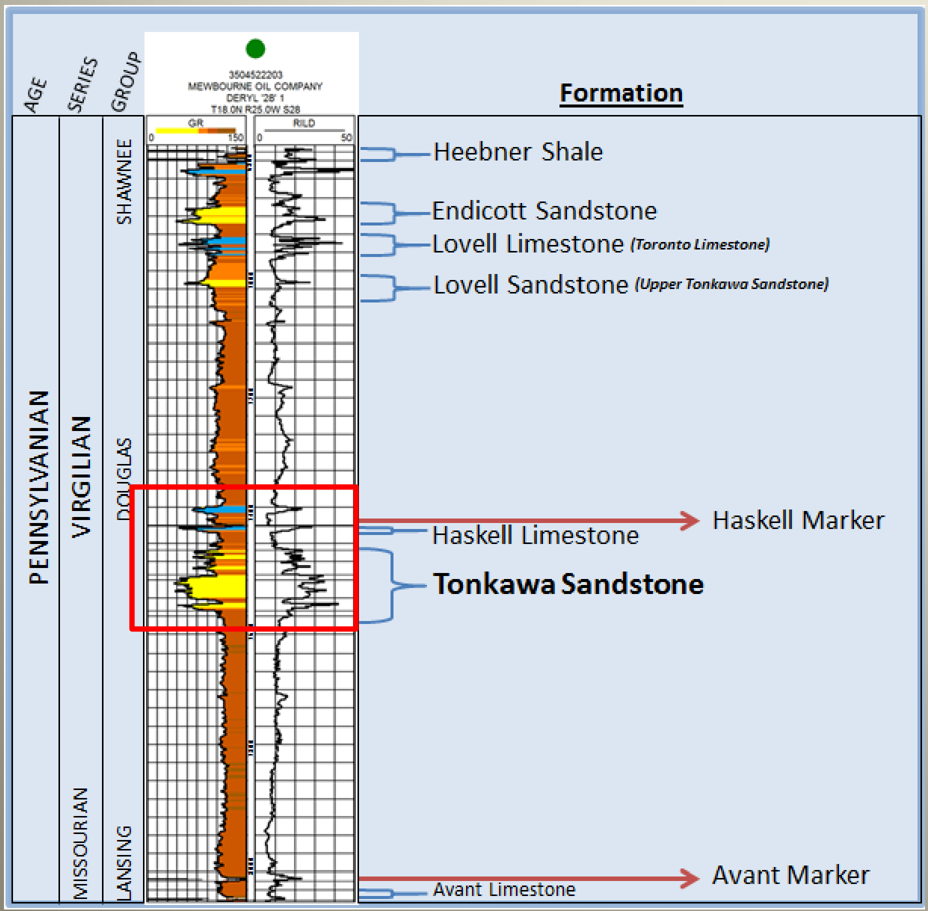
GROUP	UNIT
Shawnee/Cisco	Topeka Ls Pawhuska Ls Hoover Ss Elgin Ss Oread Ls Heebner Sh Endicott Ss
Douglas/Cisco	Lovell Ls Haskell Ls **Tonkawa Ss**
Lansing/Hoxbar	Avant Ls Cottage Grove Ss

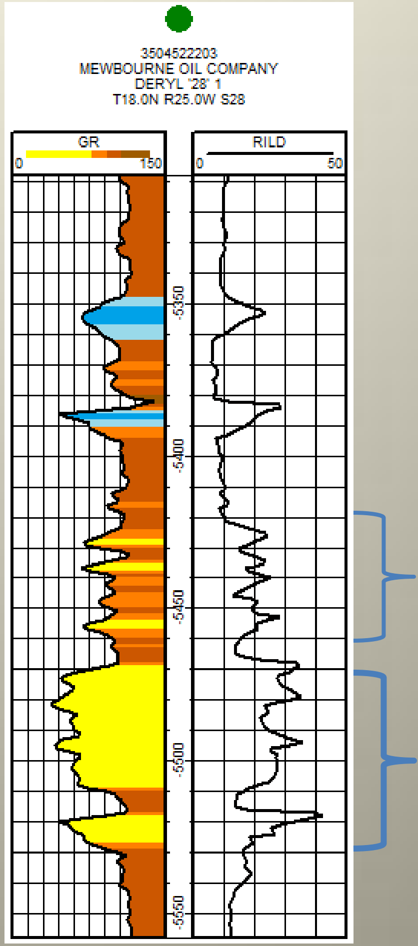
Geologic Setting

Type Well

Location Map







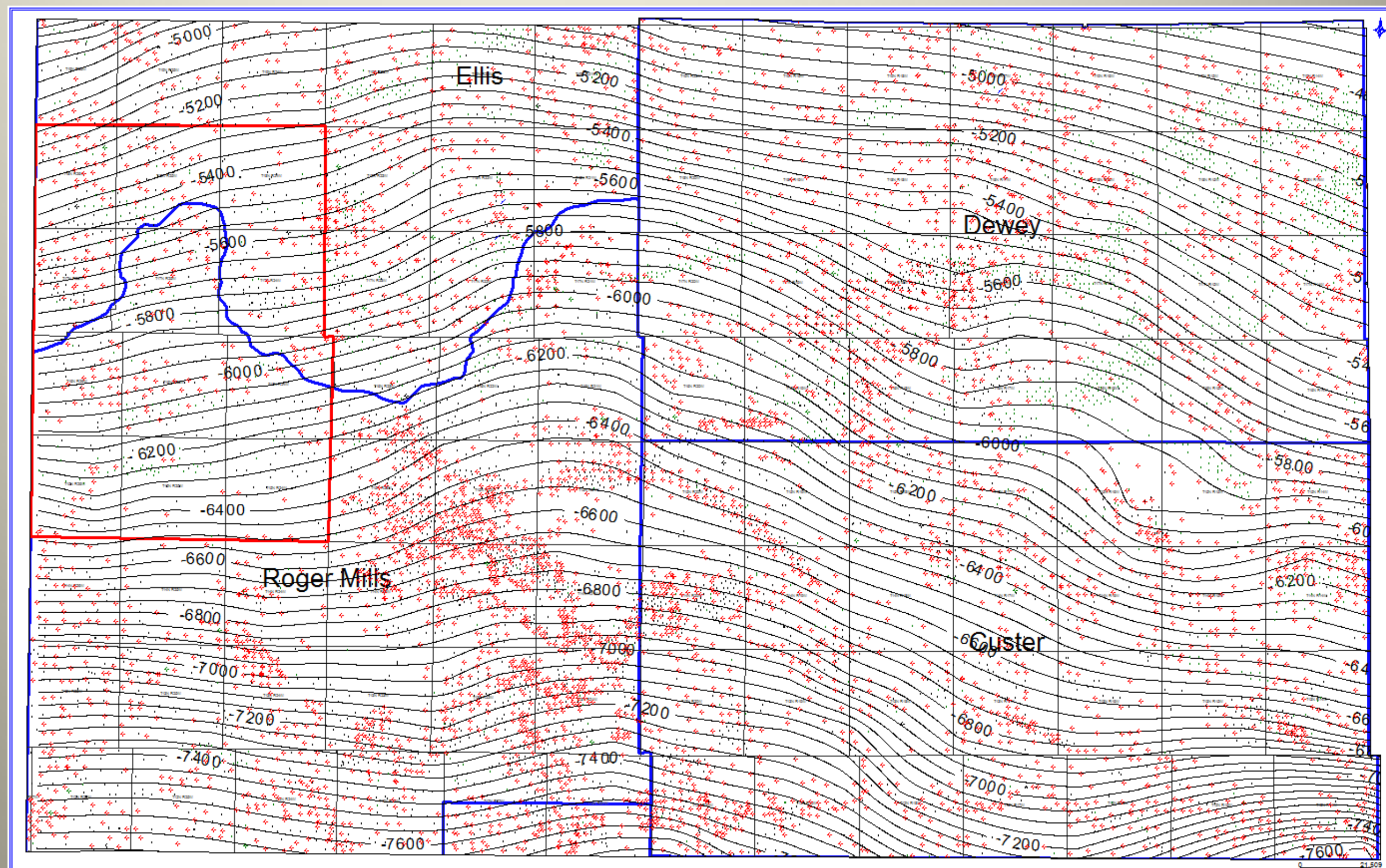
Upper Unit

Lower Unit

Geologic Setting

Regional Structure – Haskell Limestone

- Structural dip of 45-60 feet per mile to the south-southeast
- Dip reaches 100 feet per mile in southeastern Custer County

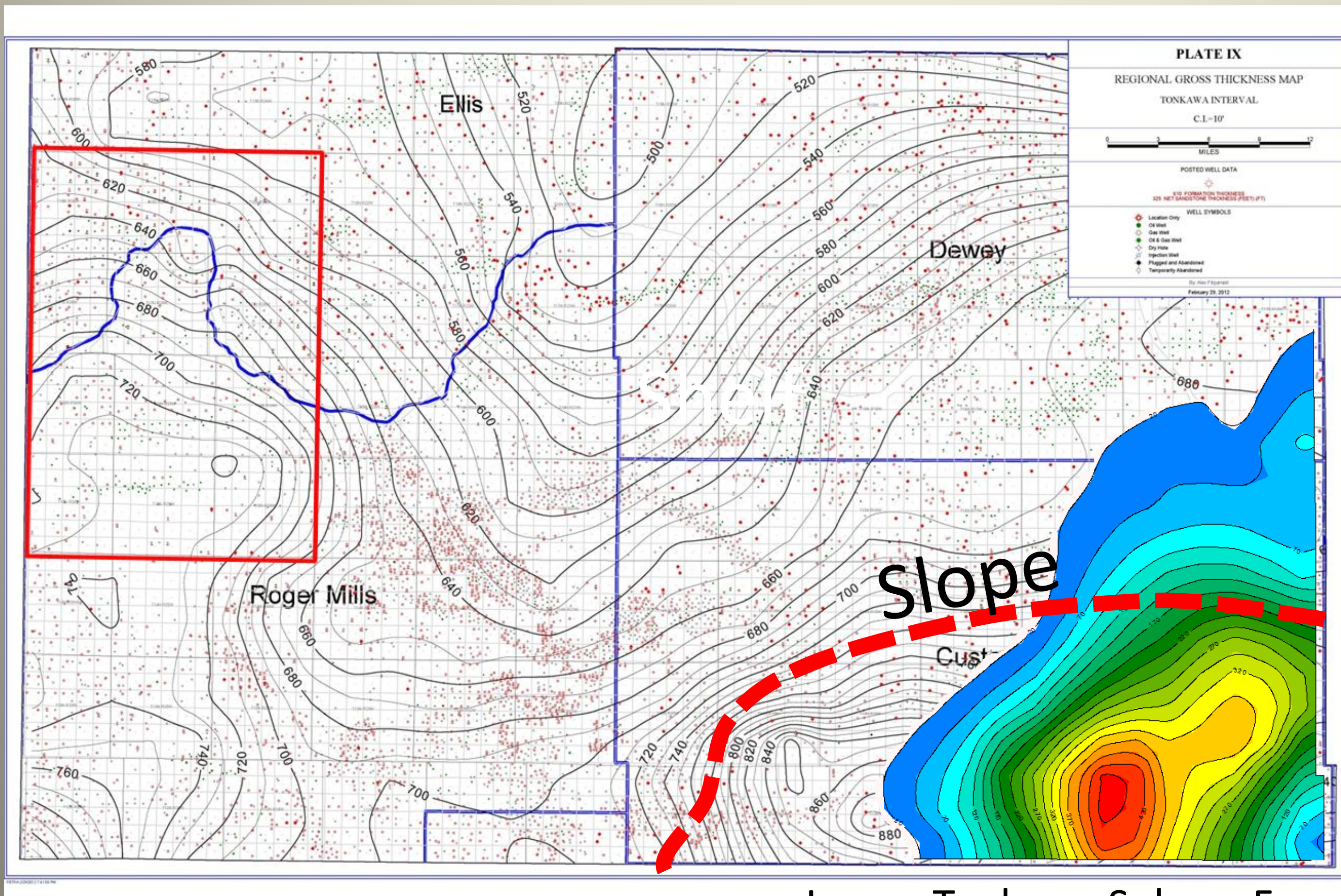


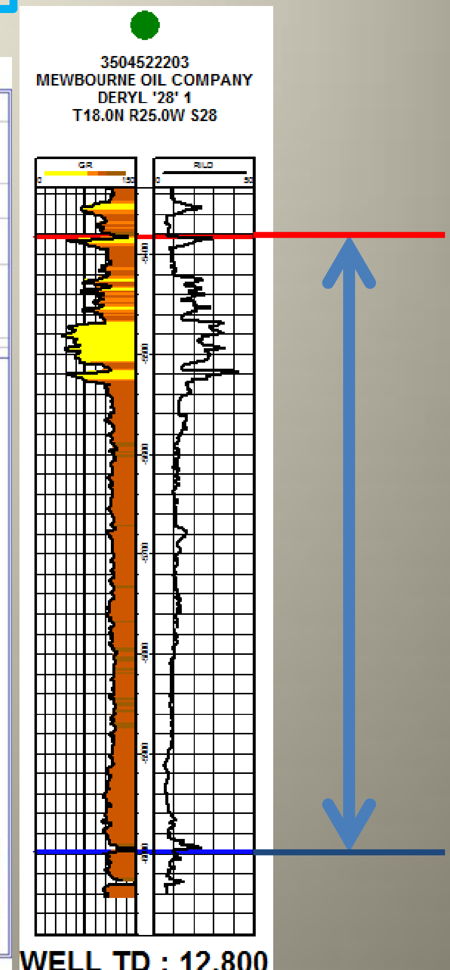
C.I. = 50 feet

Datum = mean sea level

Geologic Setting

Tonkawa Interval Thickness





Lower Tonkawa Subsea Fan
(Kumar and Slatt, 1984)

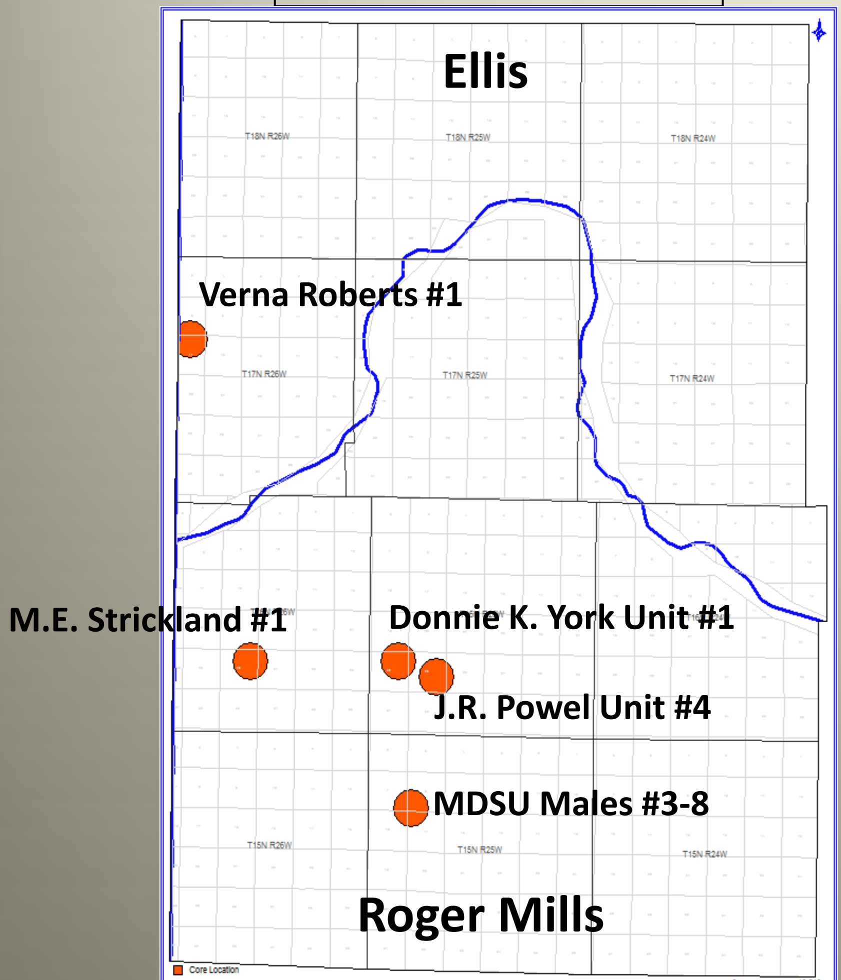
Determining Depositional Environment

- Sedimentary Structures in Core
- Geometry of Sandstones from Wireline Logs
- Distribution of Core-calibrated Facies

Depositional Environment

Location of Cores

Location of Cores



<u>Cores</u>

Cordillera Energy Partners
- Donnie K. York Unit #1
- J.R. Powel Unit #4

Mewbourne Oil Co.
- MDSU Males #3-8

KT Energy Inc.
- M.E. Strickland #1

J. Brex
- Verna Roberts #1

Depositional Environment

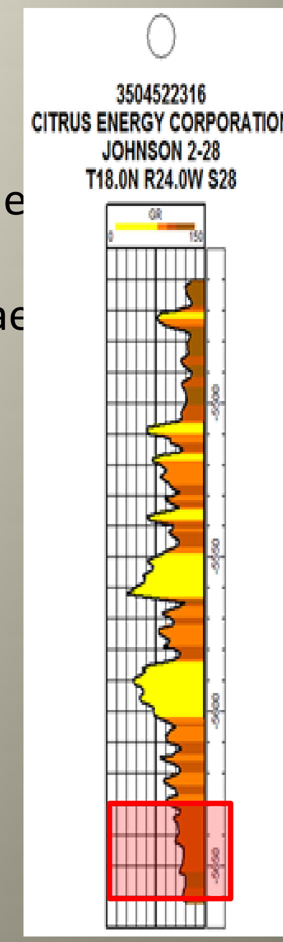
Core Analysis – Facies 1 (F1)

(J. Brex, Verna Roberts #1; slabbed core)

Observations

- Alternating fine siltstone and mudstone layers
- Parallel siltstone laminae (lenticular bedding)
- Soft-sediment deformation
- Small-scale cross-bedding
- Asymmetrical ripples
- Flame Structures
- Horizontal burrowing

Geometry



Log Response

Cleaning/coarsening Upward

Depositional Environment

Core Analysis – Facies 2 (F2)

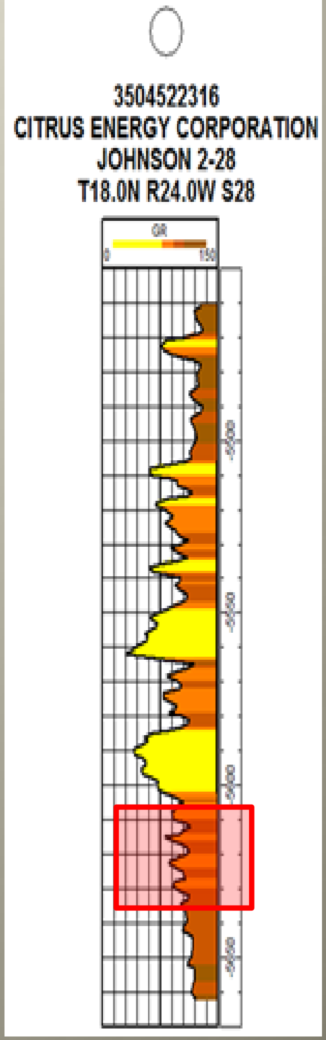
(Mewbourne Oil, MDSU Males #3-8; slabbed core)

Observations

- Laminated siltstone, silty sandstone, and mudstone
- Graded Bedding
- Small-scale cross-bedding
- Symmetrical ripples

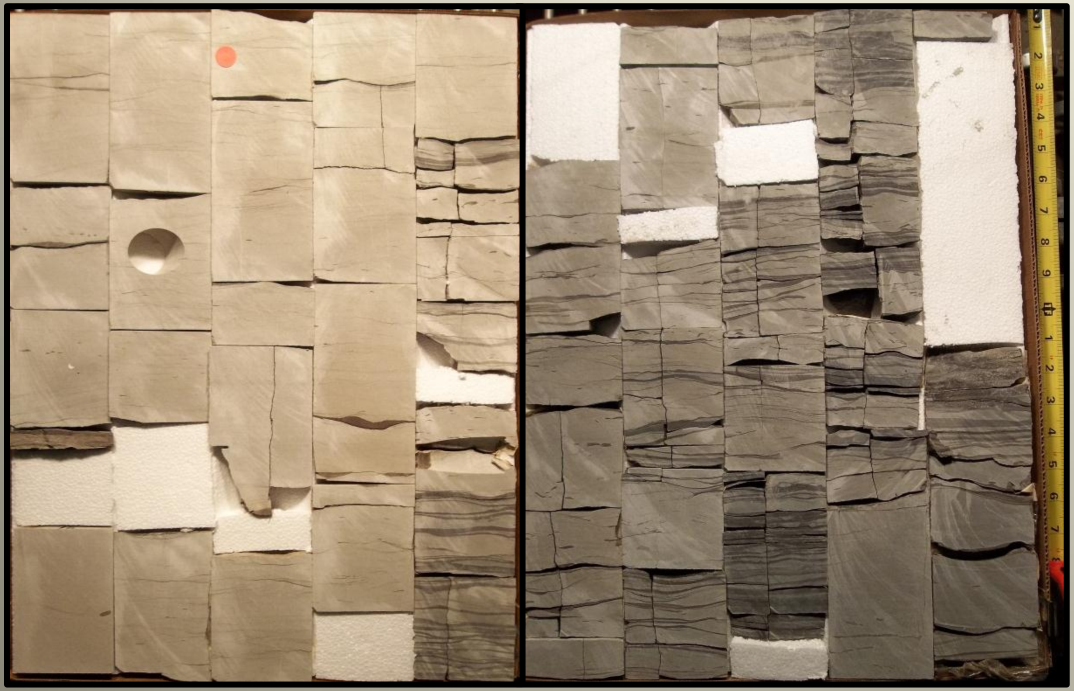
Cleaning/coarsening Upward

Geometry



Depositional Environment

Core Analysis – Facies 3 (F3)

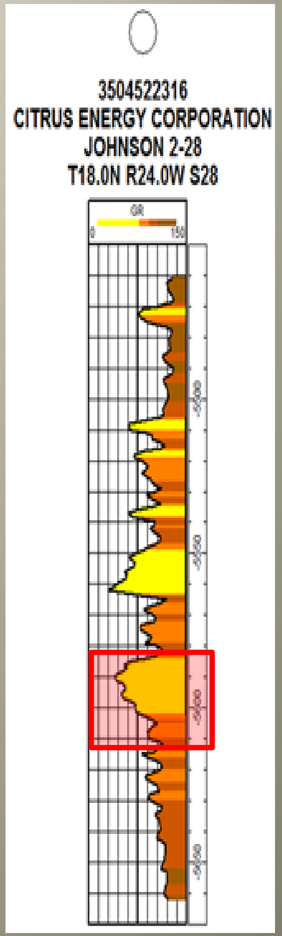


(Mewbourne Oil, MDSU Males #3-8; slabbed core)

Observations

- Transition to clean, well sorted sandstone
- Gradational basal contact
- Small-scale cross-bedding
- Symmetrical and asymmetrical ripples
- Abundant mica

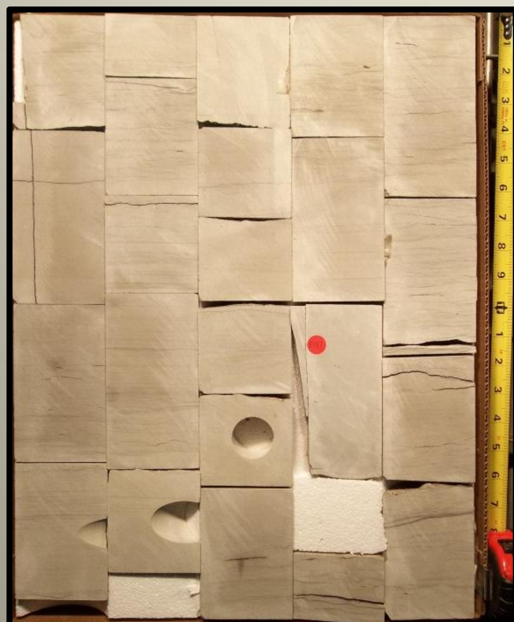
Geometry



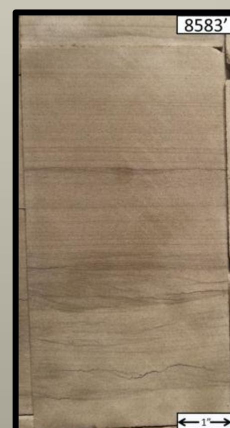
Cleaning/coarsening Upward to Symmetrical Sandstone

Depositional Environment

Core Analysis – Facies 4 (F4)



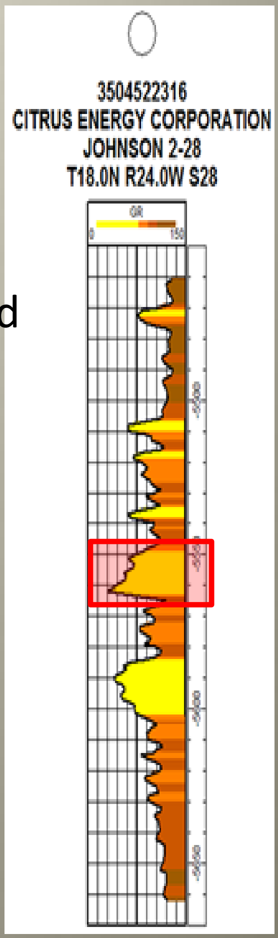
(Mewbourne Oil, MDSU Males #3-8; slabbed core)



Observations

- Clean, moderately sorted sandstone
- Occasionally fining upward
- Sharp, possibly erosive basal contact
- Small-scale cross-bedding
- Asymmetrical ripples
- Planar Bedding
- Clay clasts and drapes

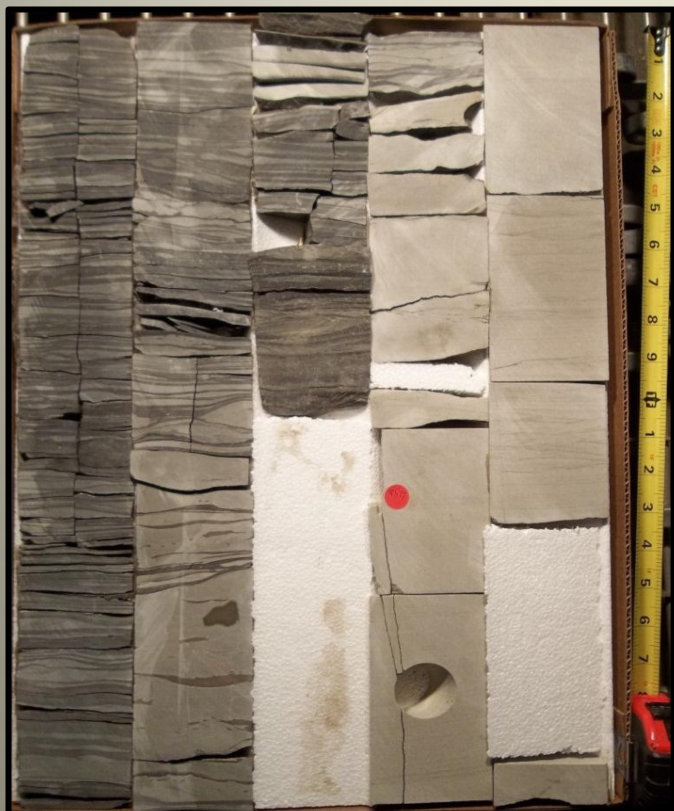
Geometry



Fining Upward

Depositional Environment

Core Analysis – Facies 5 (F5)

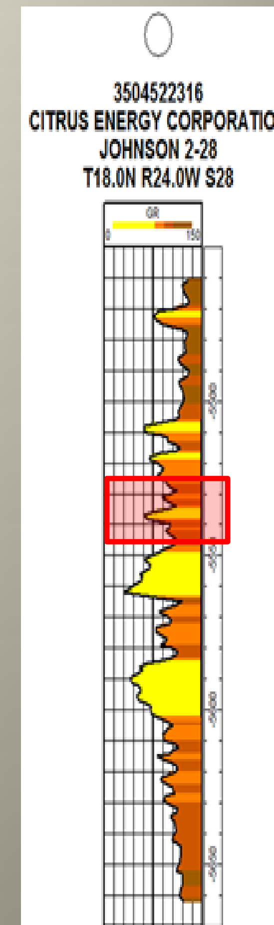


(Mewbourne Oil, MDSU Males #3-8; slabbed core)

Observations

- Alternating fine siltstone and mudstone layers
- Occasionally interbedded very fine sandstone
- Small-scale cross-bedding
- Clay clasts and drapes
- Organic debris

Geometry

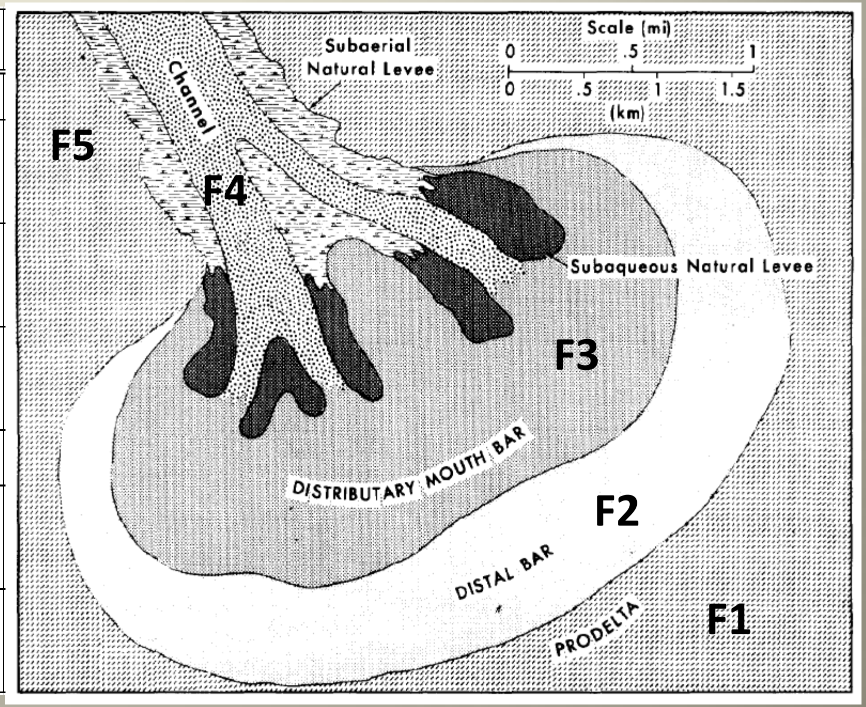


Thin Symmetrical- No Defined Trend

Depositional Environment

Interpretation

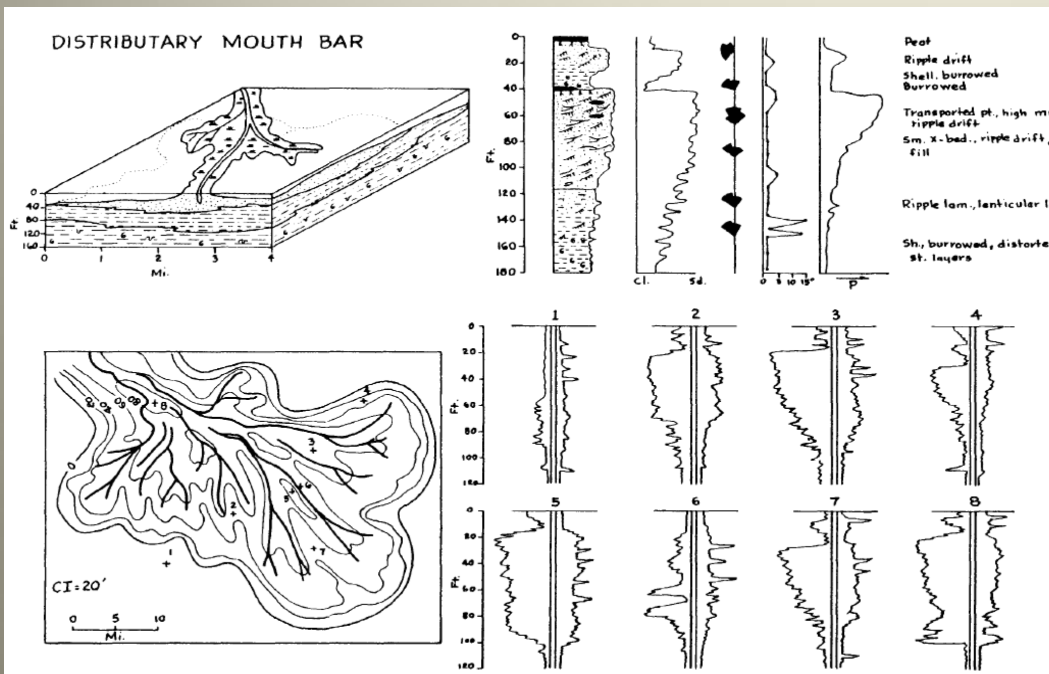
	Facies	Observed Lithology	Grain Size	Dominant Features
	Subaqueous Deltaic			
F1	Prodelta	Siltstone-Mudstone	Clay to fine silt	Lenticular bedding Symmetrical ripples Burrows
F2	Distal Bar (Delta Front)	Silty Sandstone-Siltstone-Mudstone	Clay to very fine	Graded Bedding Symmetrical ripples X-beds
F3	Distributary Mouth Bar	Sandstone	Very fine to fine	Gradational basal contact Symmetrical & asymmetrical ripples
	Subaerial Deltaic			
F4	Distributary Channel Fill	Sandstone	Very fine to fine	Sharp basal contact Asymmetrical ripples Clay clasts
F5	Interdistributary Bay-Fill/ Crevasse Splay	Sandstone-Siltstone-Mudstone	Clay to very fine	Lenticular bedding Clay clasts & drapes Organic debris



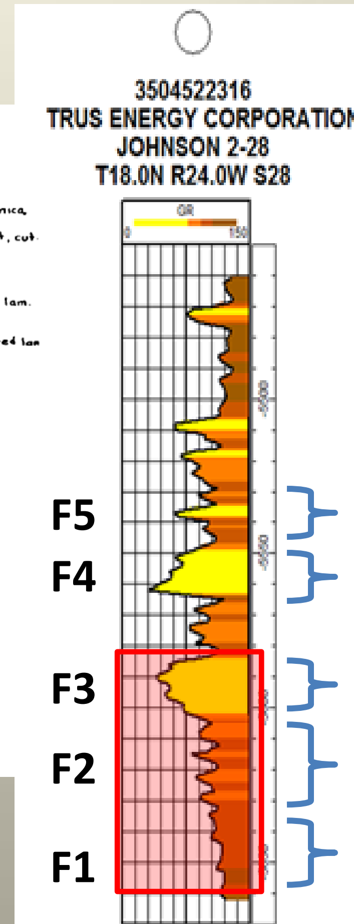
(Coleman and Prior, 1980)

Depositional Environment

Electrofacies – Delta Front & Distributary Mouth Bar



(Coleman and Prior, 1980)



Interdistributary Bay-Fill

Distributary Channel Fill

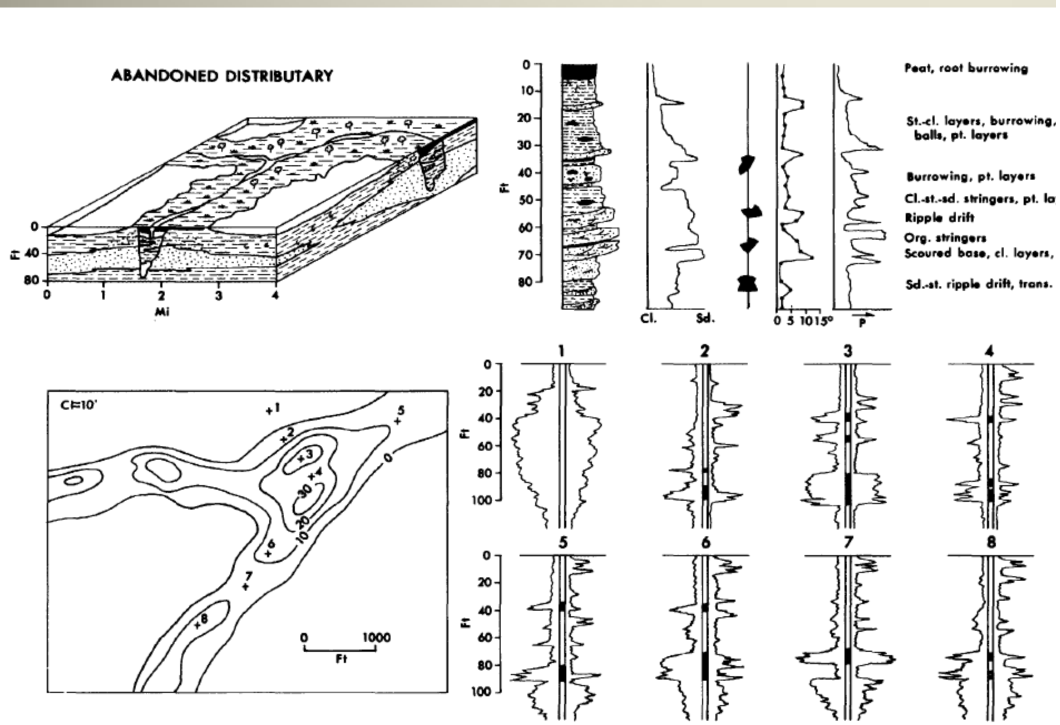
Distributary Mouth Bar

Distal Bar (Delta Front)

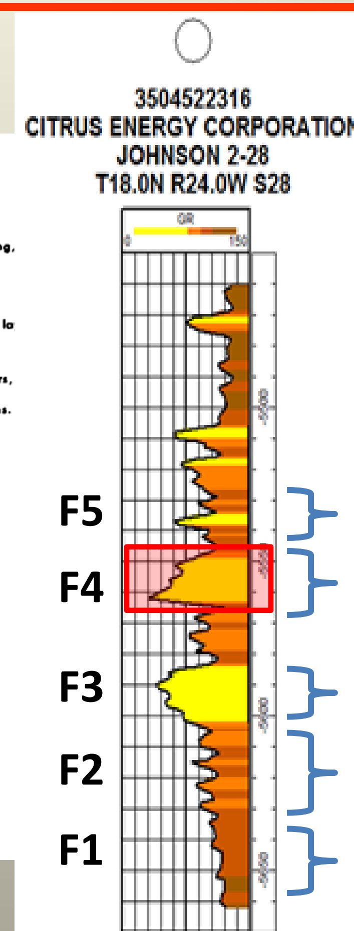
Prodelta

Depositional Environment

Electrofacies – Distributary Channel Fill



(Coleman and Prior, 1980)



F5 – Interdistributary Bay-Fill

F4 – Distributary Channel Fill

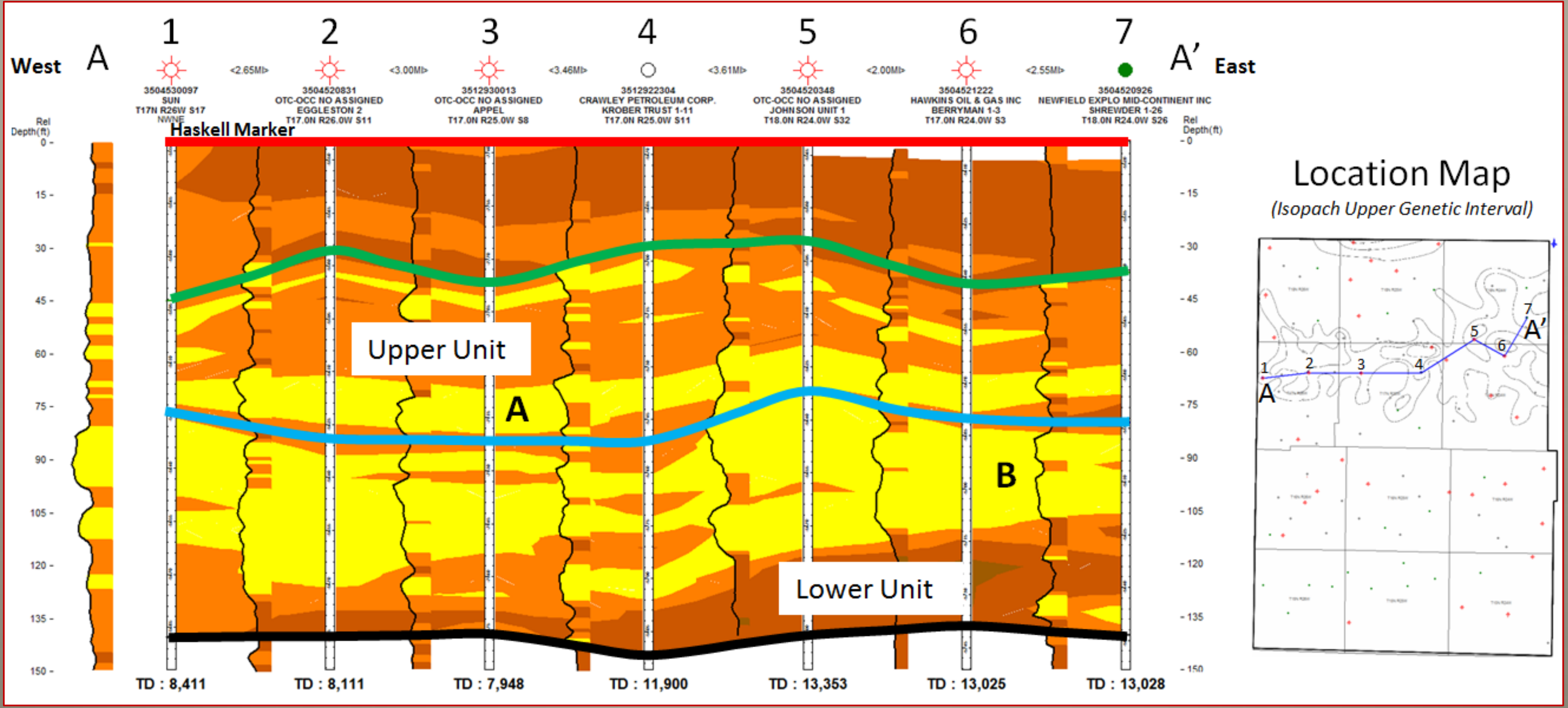
F3 – Distributary Mouth Bar

F2 – Distal Bar (Delta Front)

F1 – Prodelta

Distribution of the Tonkawa Sandstone

Distribution of the Tonkawa Sandstone

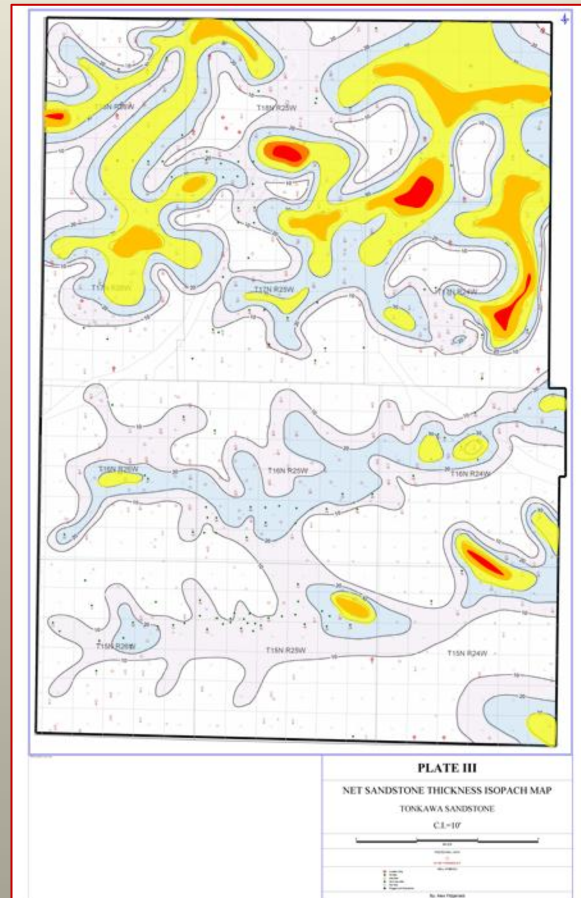


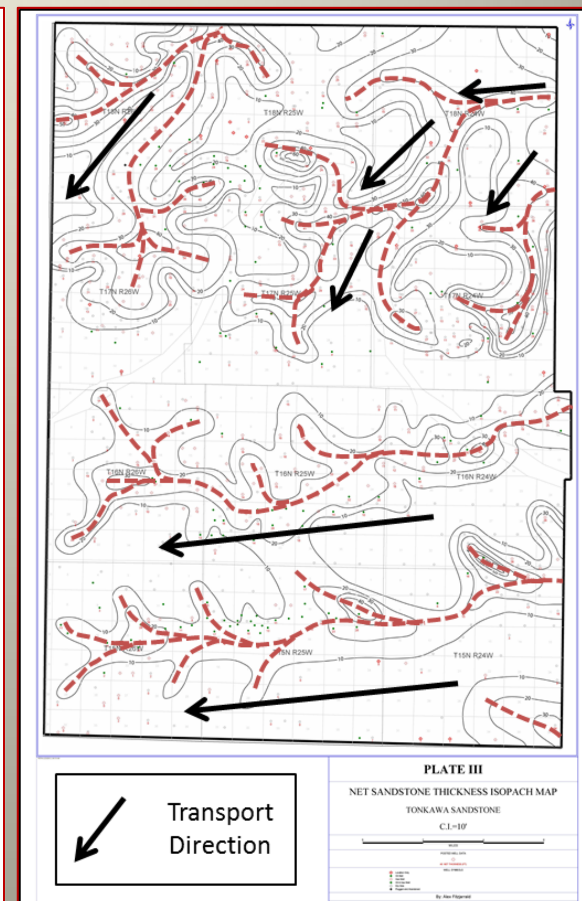
Distribution of the Tonkawa Sandstone

Net-Sandstone Thickness

Net-Sandstone Thickness Map

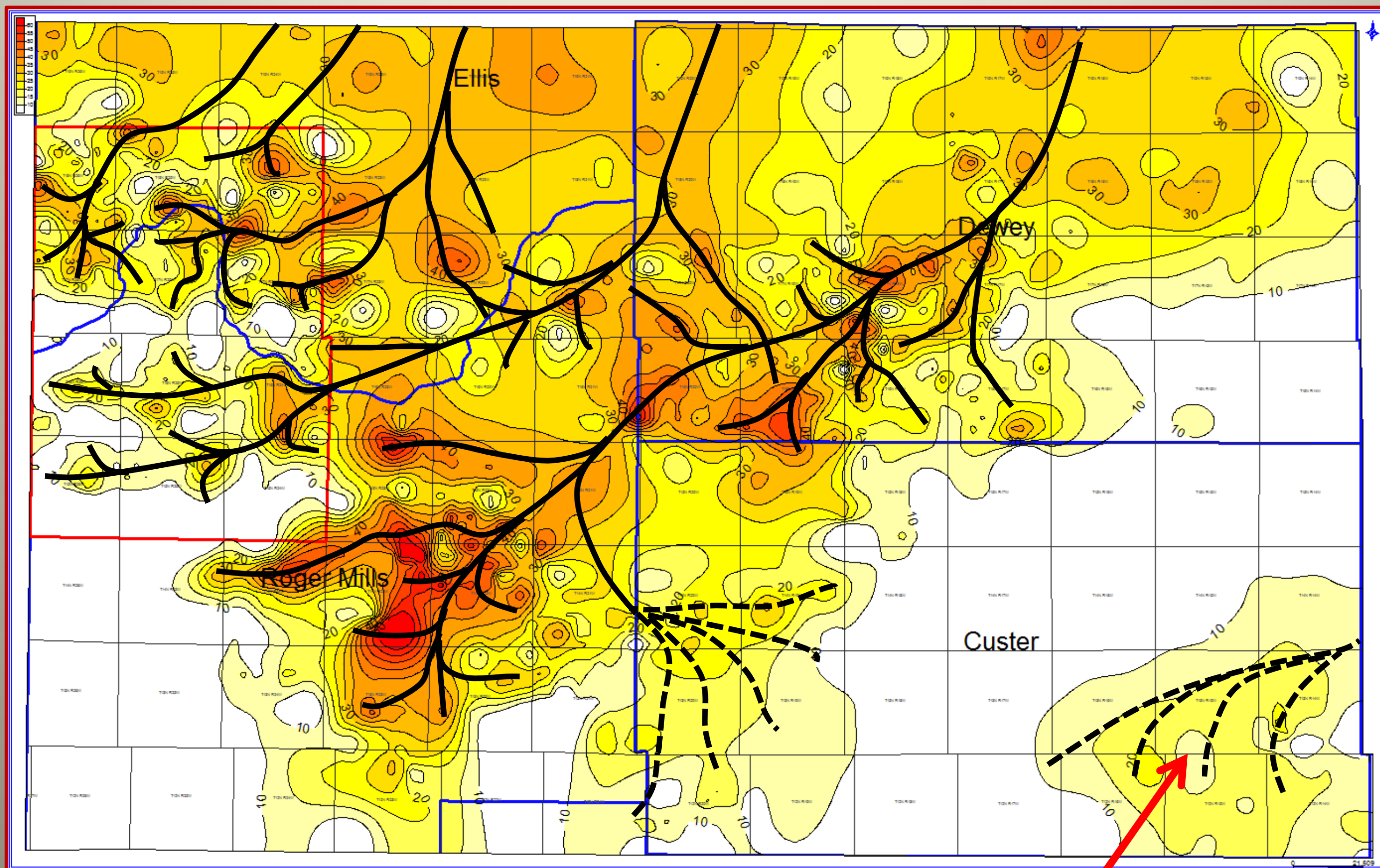
- Generated with gamma-ray wireline logs
- Sandstone was selected using a shale volume < 40%
- Highly digitate and bifurcating distribution patterns emerge





Distribution of the Tonkawa Sandstone

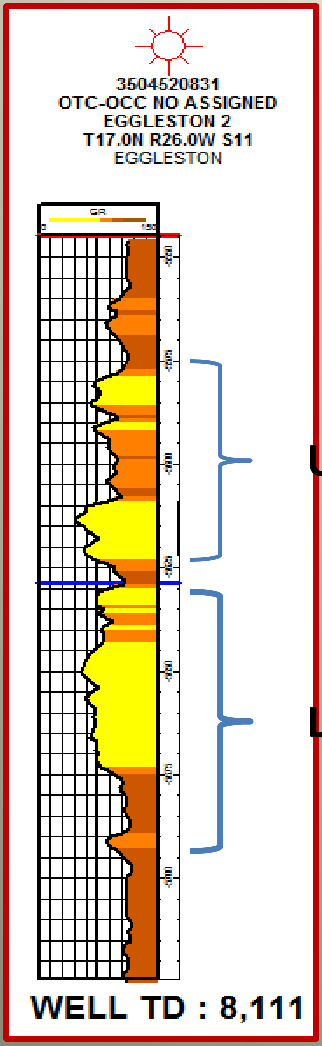
Regional Sandstone Thickness



(Submarine Fan Deposits)

Distribution of the Tonkawa Sandstone

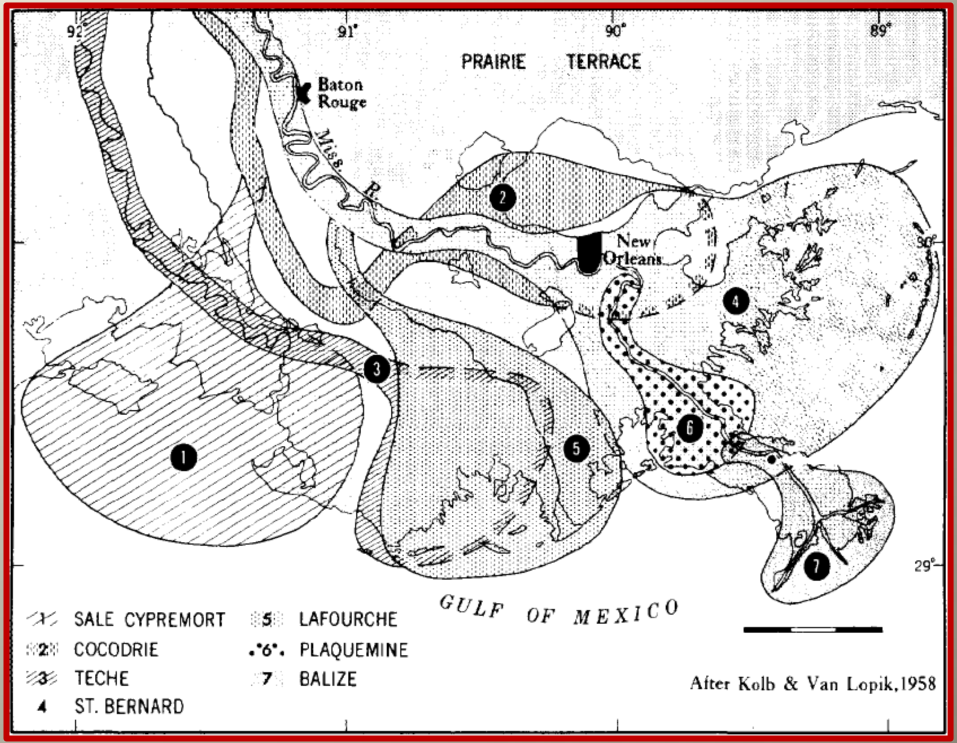
Depositional Events



Upper Unit

Lower Unit

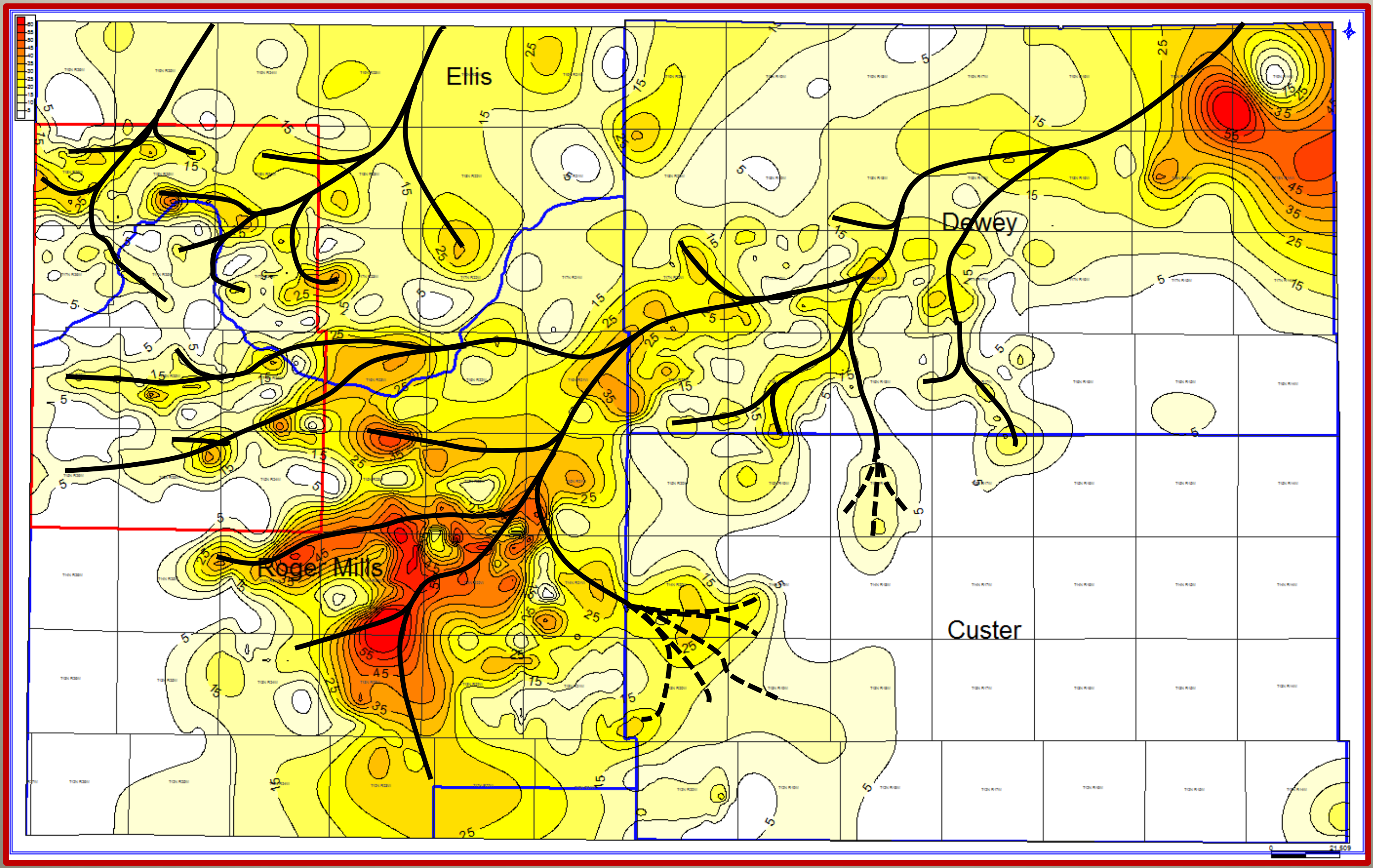
Deltaic Lobes of the Modern Mississippi River

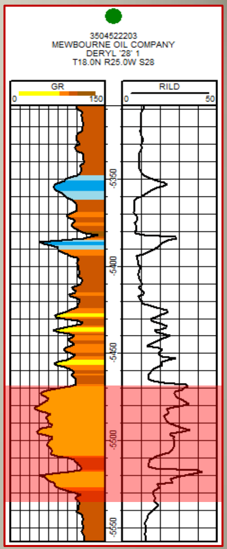


(Coleman and Prior, 1980)

Distribution of the Tonkawa Sandstone

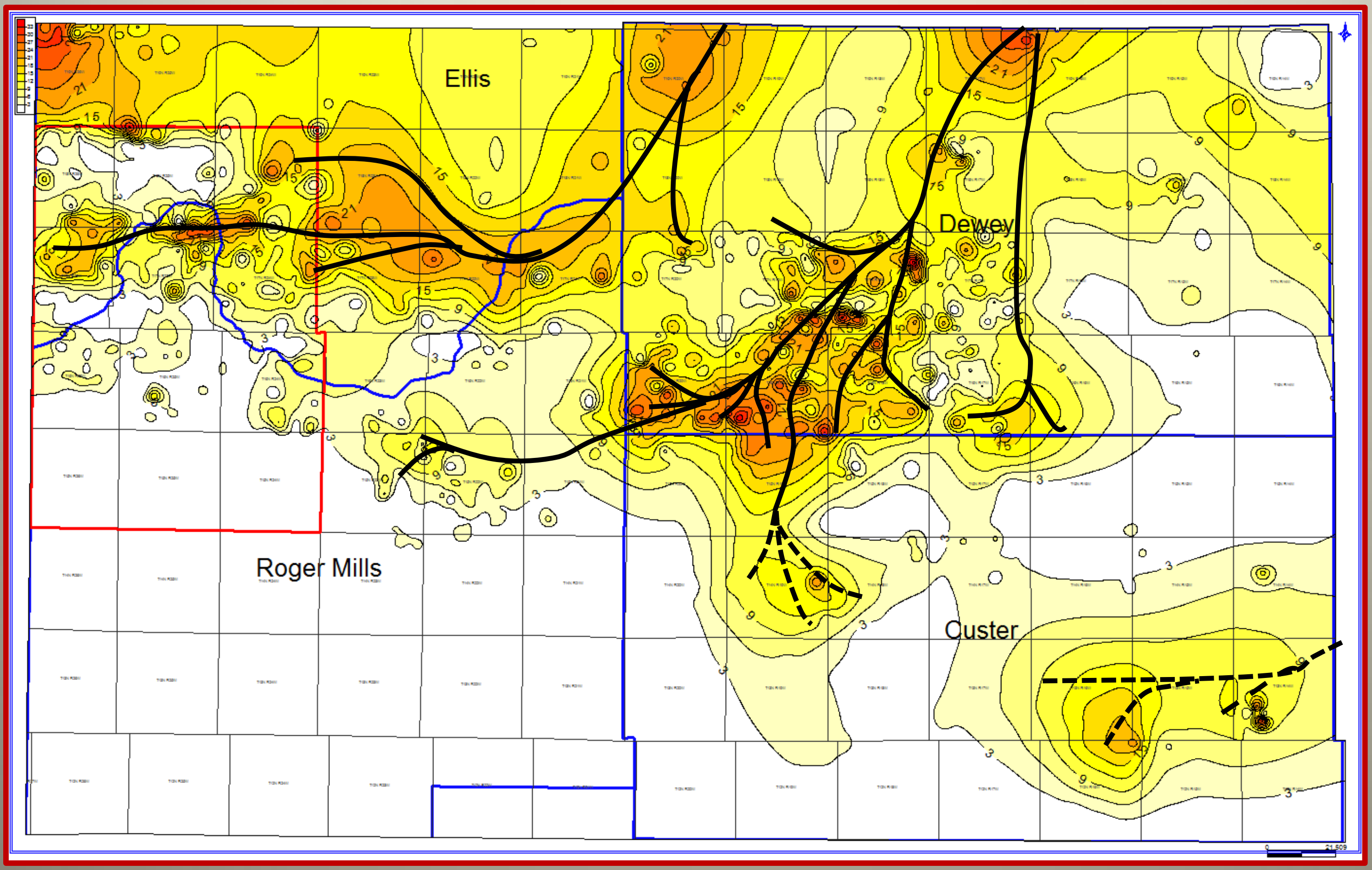
Lower Unit

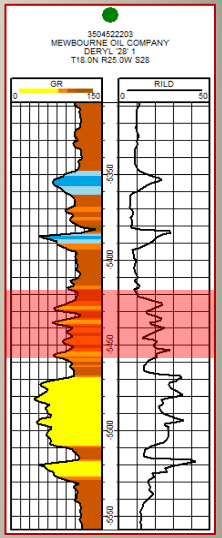




Distribution of the Tonkawa Sandstone

Upper Unit

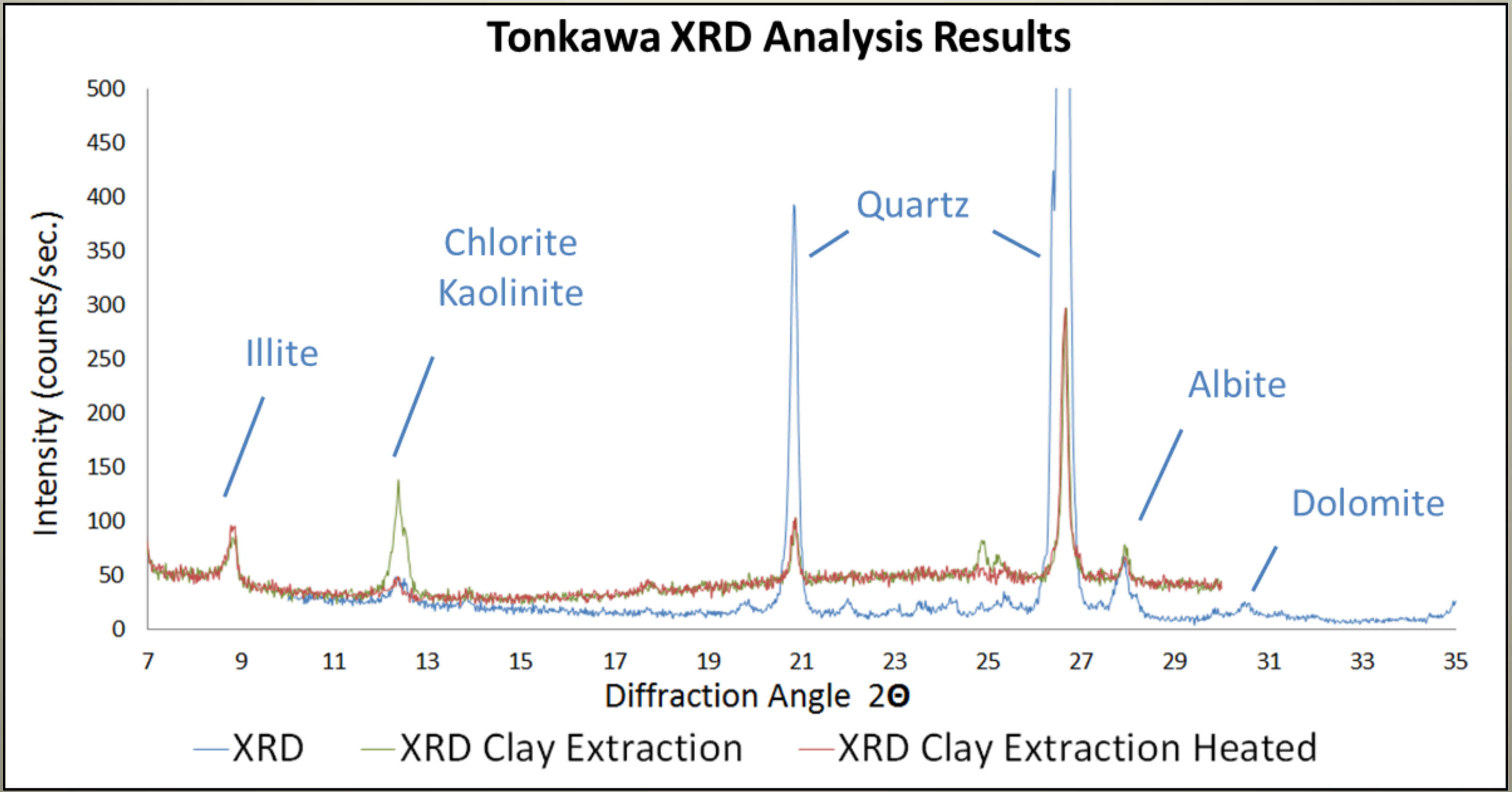




Petrographic Analysis

Petrographic Analysis

X-Ray Diffraction Results

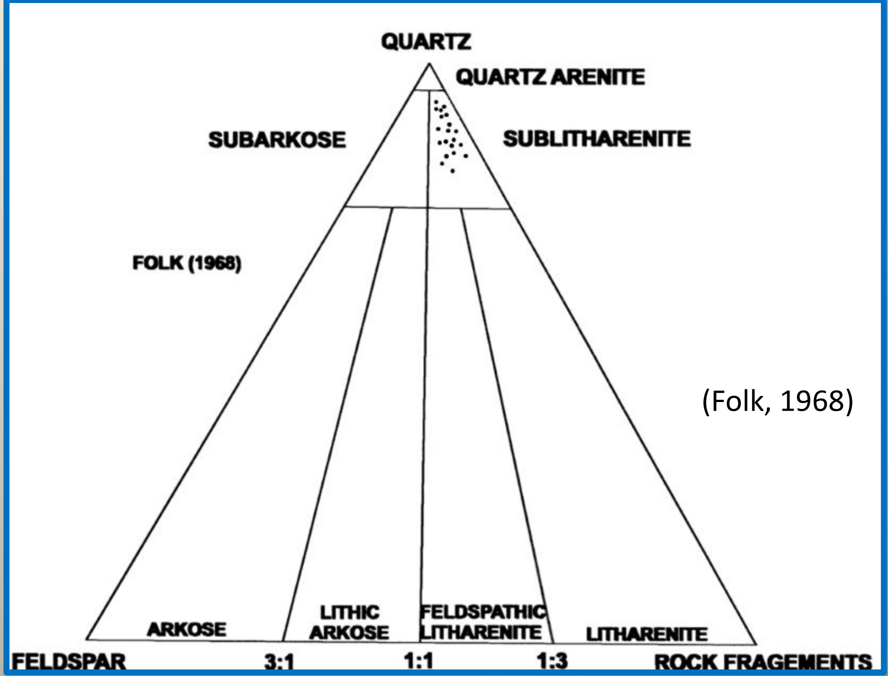


Petrographic Analysis

Detrital Constituents

AVERAGE PERCENTAGES OF DETRITAL CONSTITUENTS

Constituent	Average Percentage
Quartz	**52.8**
Rock Fragments	**6.4**
Metamorphic	3.6
Sedimentary	2.2
Chert	0.6
Feldspars	**2.1**
Albite	1.6
Orthoclase	0.3
Microcline	0.1
Muscovite	**3.7**
Zircon	**0.6**
Chlorite/Biotite	**trace**
Carbonaceous Material	**0.4**
Tourmaline	**0.3**
Glauconite	**0.2**
Detrital Matrix	**trace**
Fossil Fragments	**trace**



(Folk, 1968)

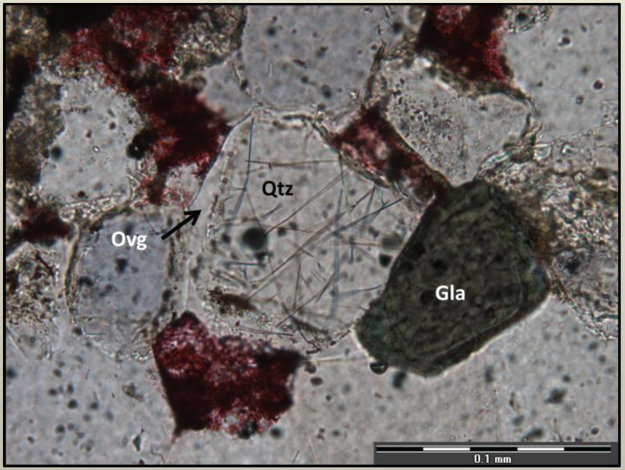
Texture	
Sorting	Good to Moderate
Sphericity	Sub-angular to Sub-rounded
Grain Size	Coarse Silt to Fine Sand

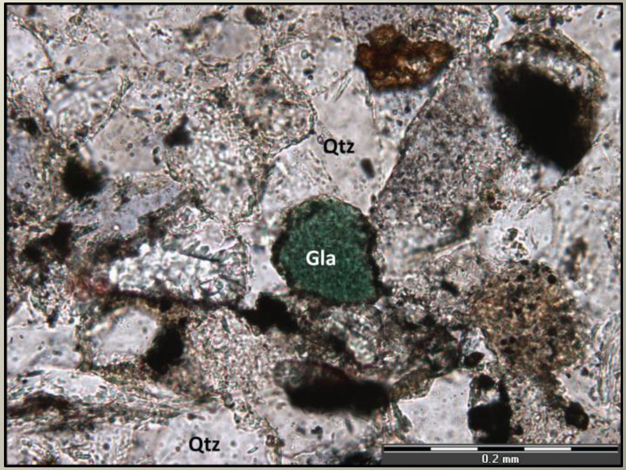
Petrographic Analysis

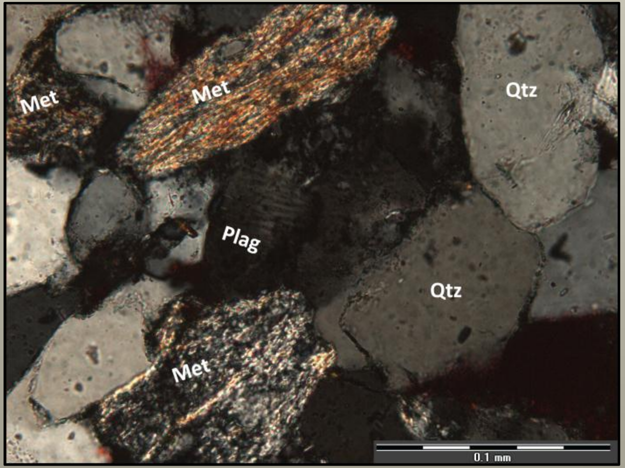
Detrital Constituents

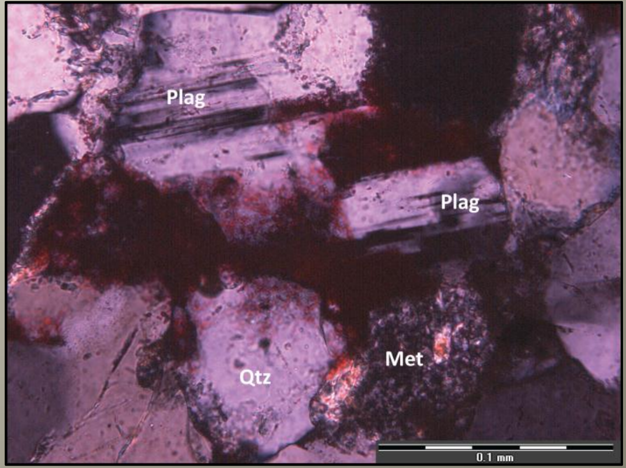
<u>Detrital Framework Grains</u>

- Quartz
- Rock Fragments
- Feldspar







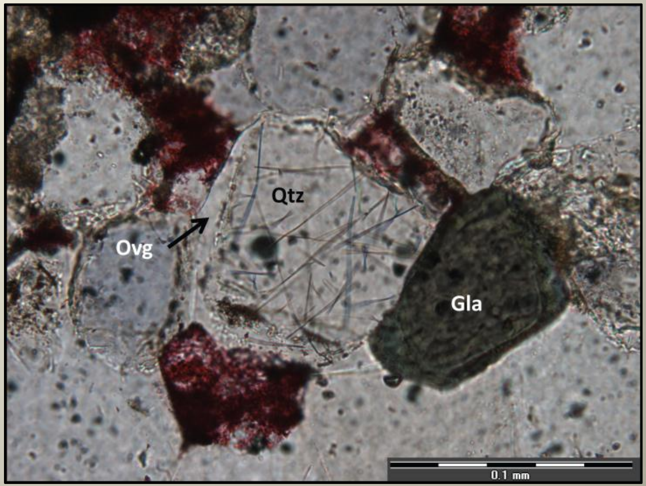


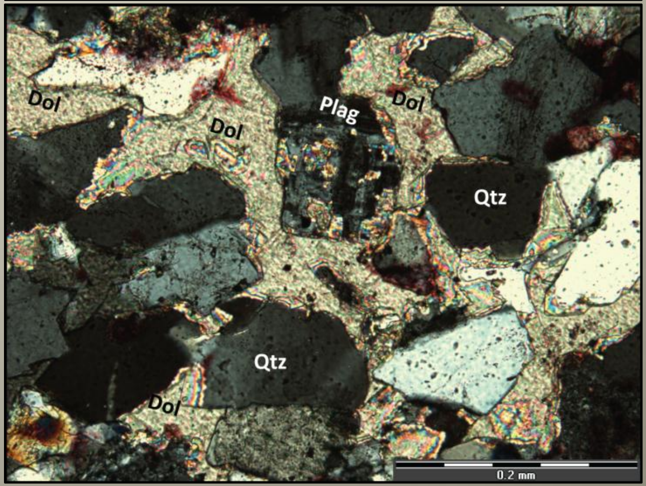
Petrographic Analysis

Authigenic Constituents

AVERAGE PERCENTAGES OF AUTHIGENIC CONSTITUENTS

Constituent	Average Percentage
Quartz Overgrowth	3.7
Dolomite	3.5
Calcite	2.3
Siderite	1.6
Kaolinite	0.9
Chlorite	0.6
Pyrite	0.5
Feldspar Overgrowth	trace
Illite	trace





Petrographic Analysis

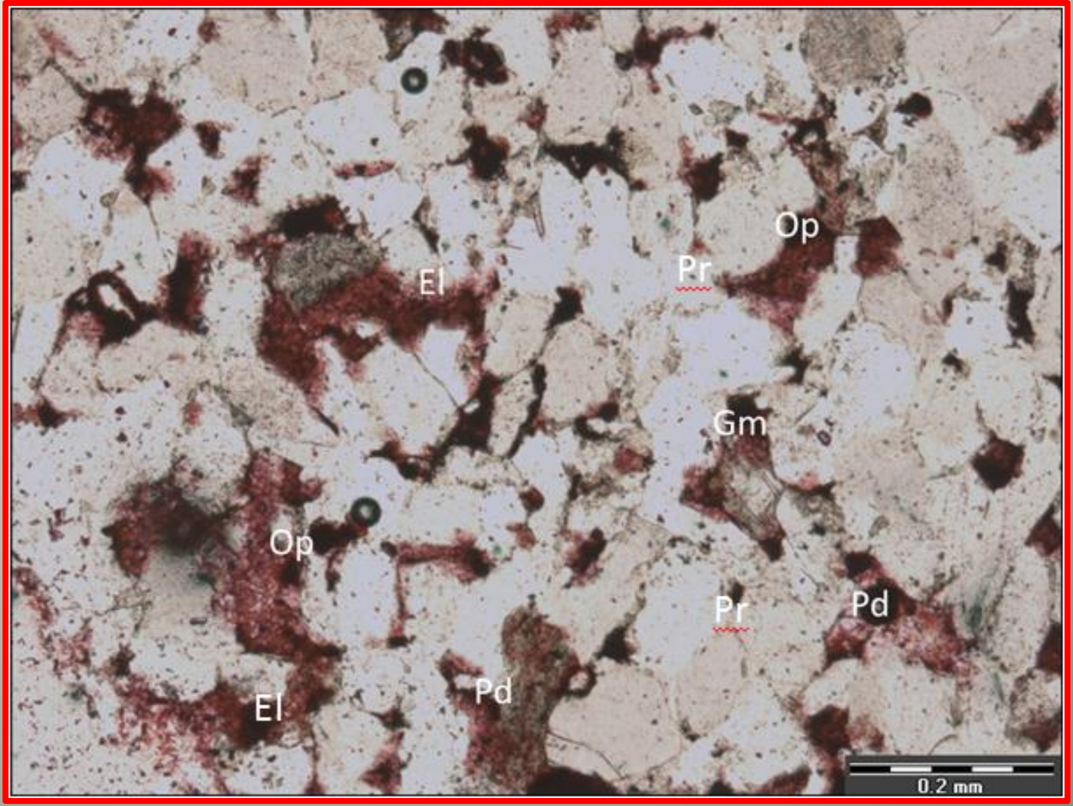
Porosity

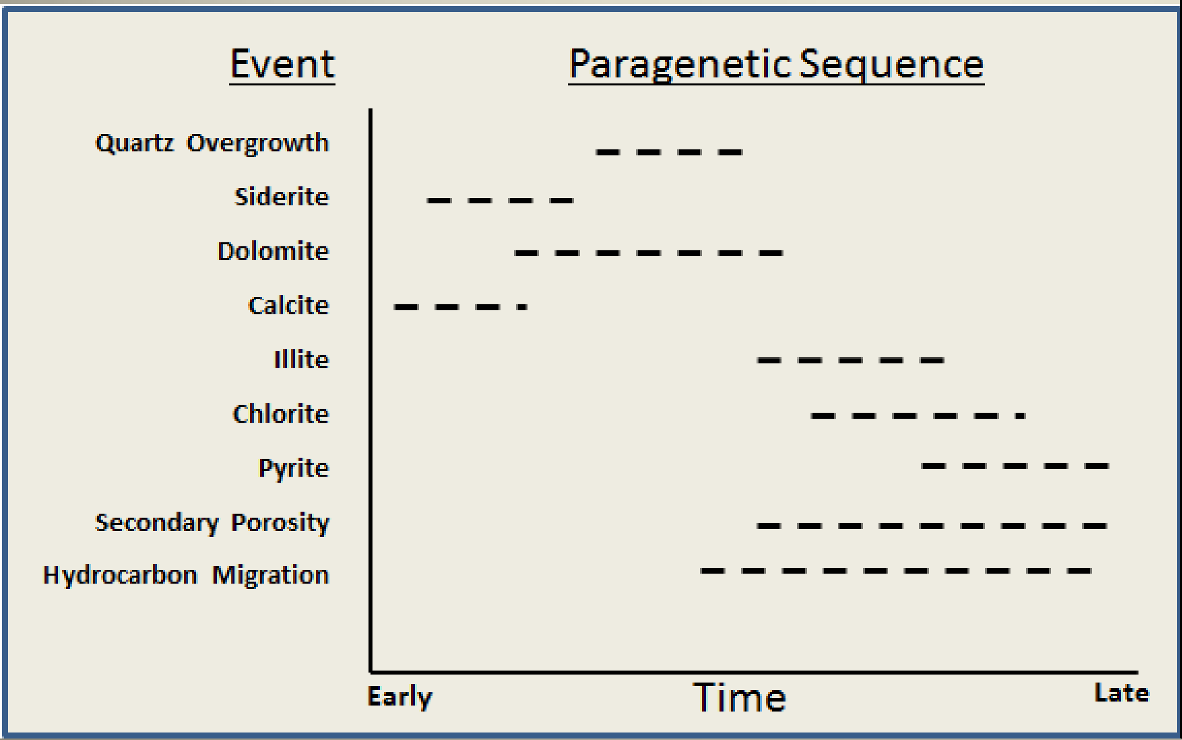
Secondary Porosity

- Partial Dissolution (Pd)
- Grain Mold (Gm)
- Oversize Pore (Op)
- Elongate Pore (El)

- Small amounts of primary porosity (Pr) can still be recognized in the Tonkawa Sandstone

Porosity: 3.5 to 15.8 percent



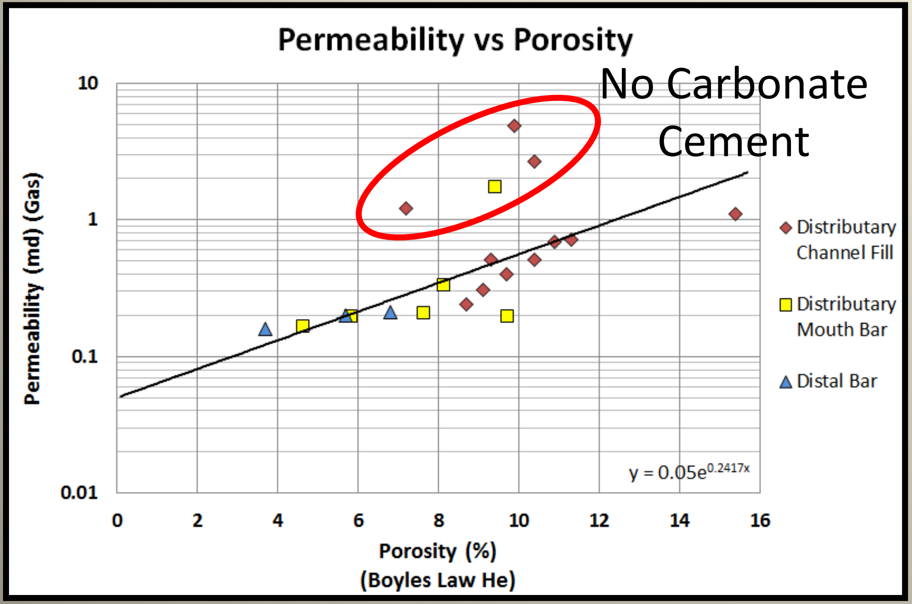

Event
Paragenetic Sequence
Quartz Overgrowth
Siderite
Dolomite
Calcite
Illite
Chlorite
Pyrite
Secondary Porosity
Hydrocarbon Migration
Early
Time
Late

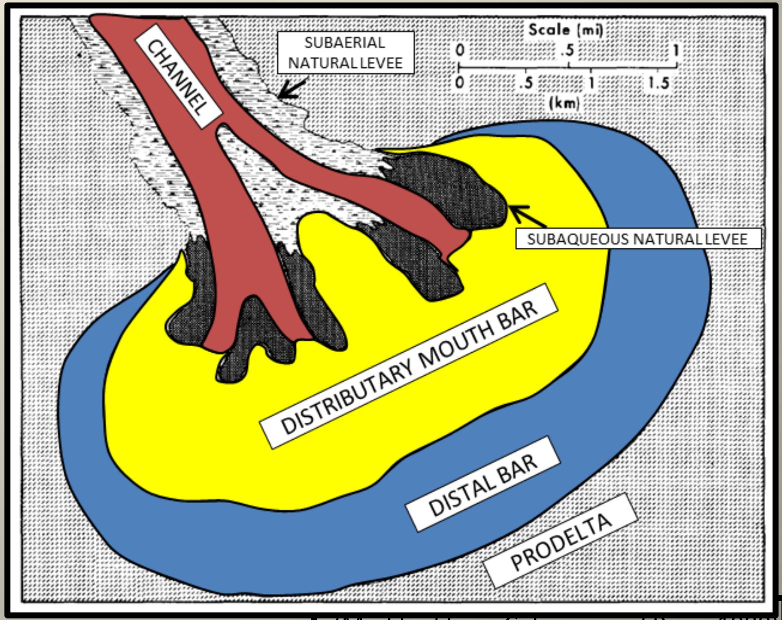

Sideritized
Clay Clast
0.2 mm

Reservoir Quality

Reservoir Quality

Permeability and Porosity





(Modified from Coleman and Prior, 1980)

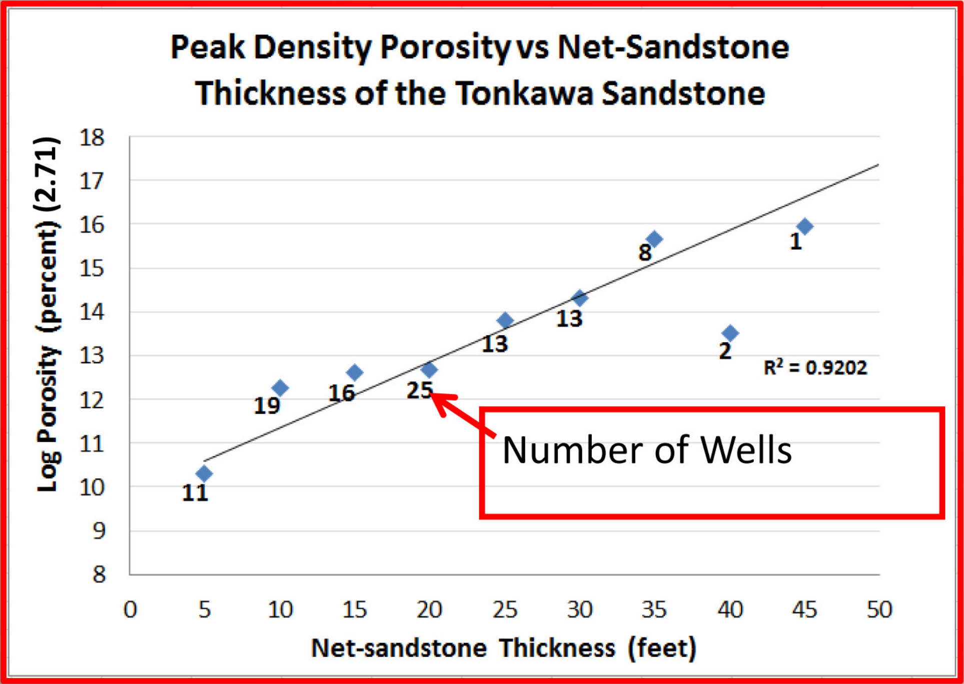
DISTRIBUTARY CHANNEL FILL		
	PERMEABILITY (MD)	POROSITY (PERCENT)
MEAN	**1.12**	**9.50**
MAX	4.86	11.30
MIN	0.21	7.20

DISTRIBUTARY MOUTH BAR		
	PERMEABILITY (MD)	POROSITY (PERCENT)
MEAN	**0.69**	**8.98**
MAX	1.78	15.40
MIN	0.17	4.60

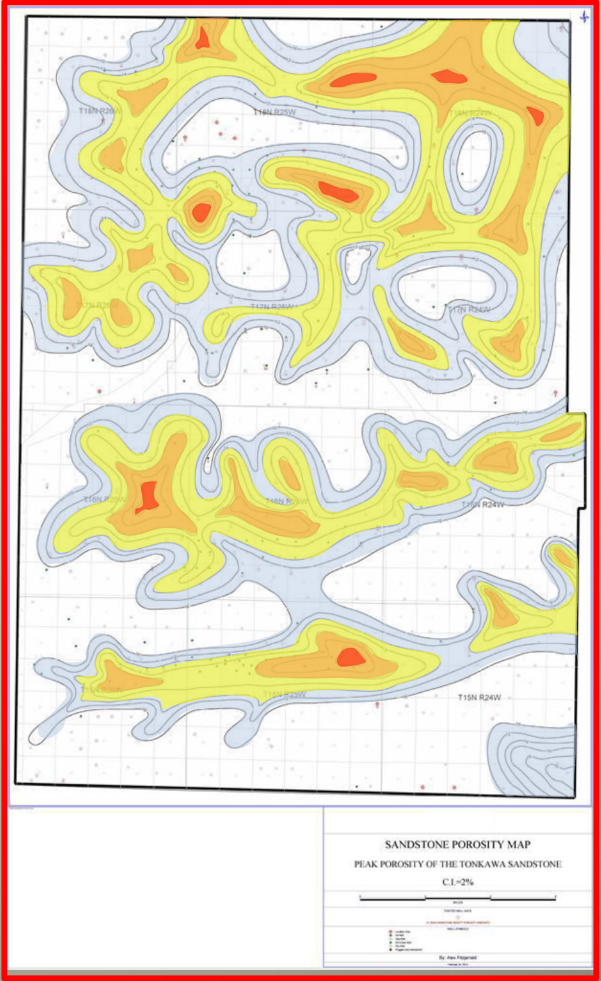
DISTAL BAR		
	PERMEABILITY (MD)	POROSITY (PERCENT)
MEAN	**0.23**	**6.08**
MAX	0.34	8.10
MIN	0.16	3.70

Reservoir Quality

Sandstone Thickness and Porosity



Isoporosity Map



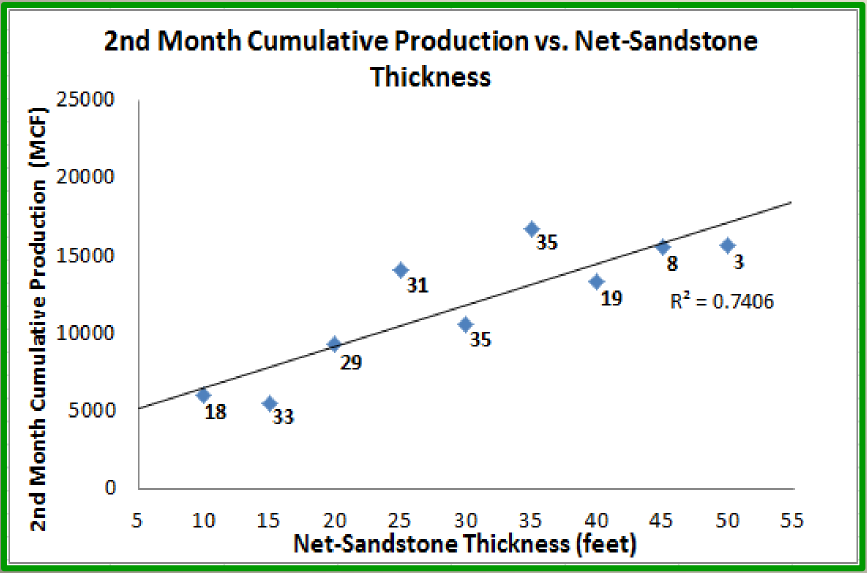
Production Characteristics

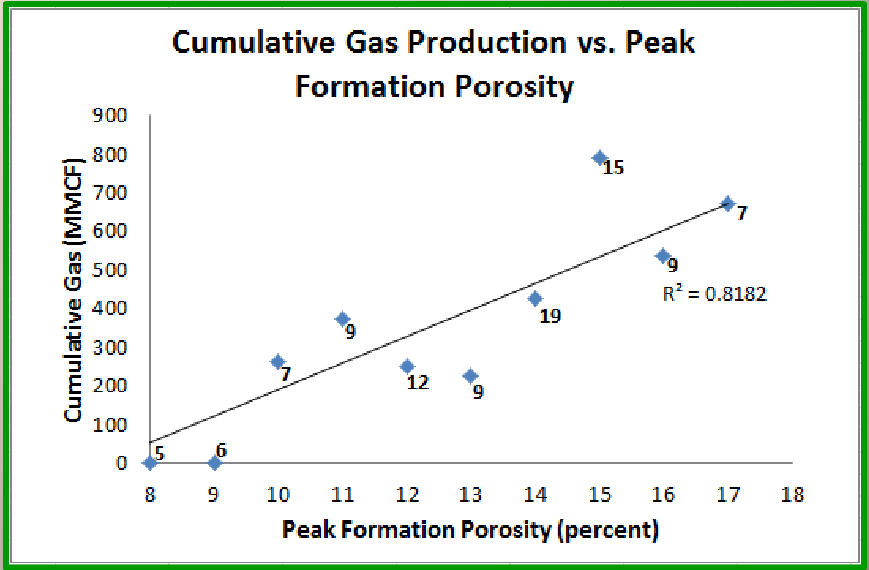
Production Characteristics

Production Rates

Net-Sandstone Thickness

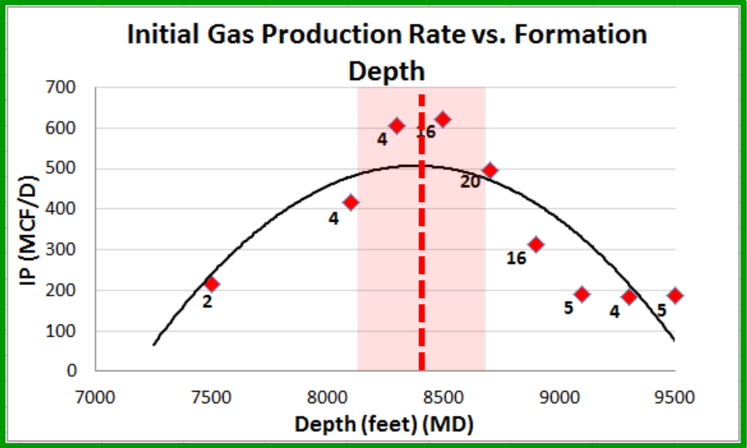
Porosity

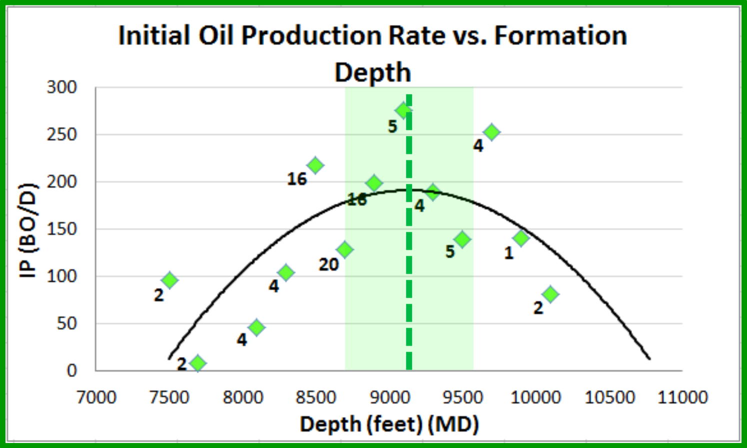




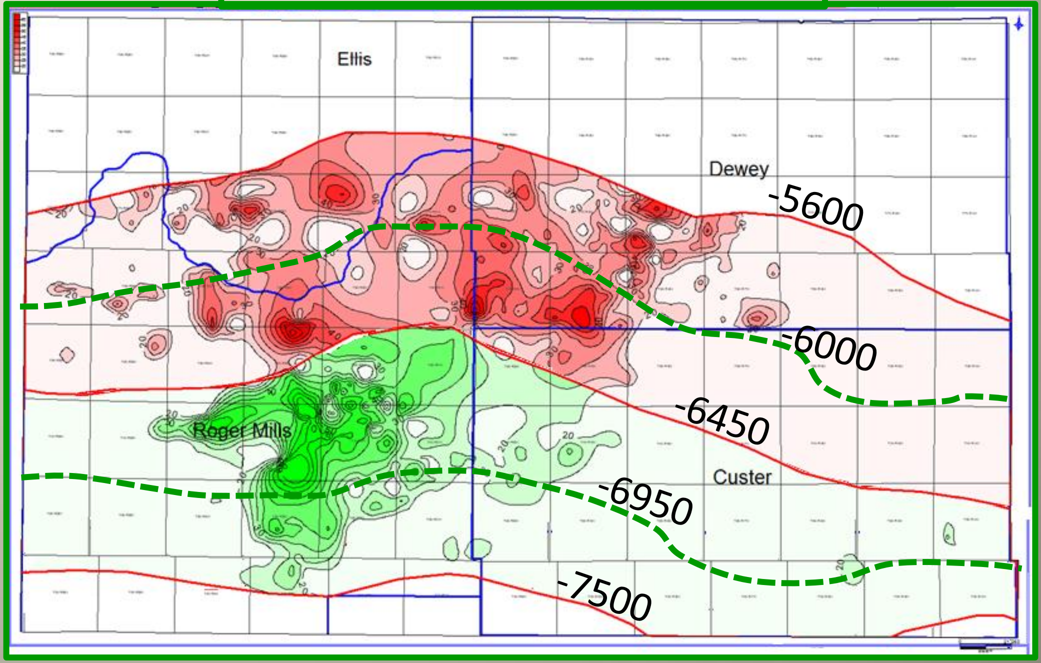
Production Characteristics

Depth – Gas vs. Liquids: Optimum Depth to Find Oil-Prone Reservoirs





Oil and Gas Prone Reservoirs



Conclusions

Conclusions: Tonkawa Sandstone

1. Deposited within a highly constructive lobate delta environment.

2. Highly digitate or “birds-foot” deltaic system much like the modern Mississippi River Delta. Lack of reworking indicates deltaic system is fluvial-dominated.

3. Potential delta-lobe switching likely related to lack of accommodation forcing lateral dispersal of sediments.

4. Secondary porosity accounts for the bulk of the porosity as primary porosity was occluded by compaction and cementation.

5. Production volumes related to net-sandstone thickness and porosity⊤ fluid type to present structural position.

6. We need to understand depositional system and facies to locate better reservoirs.

Acknowledgements

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  - Dr. Mary Hileman
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  - **Devon Energy**
- **AAPG Mid-Continent Section**

Fitzjarrald Vacuum Pump for Epoxy Impregnating Standard Core Plugs

Thank You for Attending!