Sequence Stratigraphy of the Upper Cretaceous Niobrara Formation, A Bench, Wattenberg Field, Denver Julesburg Basin, Colorado*

Lisa E. Remington LaChance[1] and Mark C. Robinson[1]

Search and Discovery Article #20176 (2012)**
Posted October 29, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

[1]Geologic Products, Drillinginfo, Inc., Austin, TX (lremington@drillinginfo.com)

Abstract

The Niobrara, like the Barnett Shale in Texas, forms a complete hydrocarbon system, as the rock itself acts as the source, reservoir, and seal. The formation contains a mix of low-permeability organic-rich chalks, marls, and shales. The lower limestone within the Niobrara is known as the Fort Hays. Overlying units are grouped together as the Smoky Hill member, which contain limestone beds named and recognized as “A”, B”, and “C” intervals or benches, in increasing depth order.

Much of the focus on oil and gas production coming out of the Niobrara has been from development of the limestone units in the middle Niobrara, or “B Bench” of the Smoky Hill Member. However, production from the A, C, and Fort Hays chalk intervals in older vertical wells suggest that they may be future targets of horizontal drilling as well.

Good well control and an abundance of digital geophysical well logs allowed for the ability to recognize and correlate several distinctive mappable units within the A Bench of the Niobrara. The focus of this study was to integrate information gleaned from gamma-ray, spontaneous potential and deep resistivity logs, scout tickets, production and completion data to construct correlations, cross sections and isopach maps of these distinctive units within the A Bench of the Niobrara.

By using major flooding surfaces and parasequence boundaries to build a stratigraphic framework to base our interpretation on, we were able to identify fault patterns that impacted the A Bench both during and after deposition. Production patterns were then matched with the depositional units interpreted during this study.

Sequence Stratigraphy of the Upper Cretaceous Niobrara Formation, A Bench, Wattenberg Field, Denver Julesburg Basin, Colorado

Lisa E. LaChance, Geologist

Mark Robinson, Director, Well and Subsurface Data

Drillinginfo, Inc.

drillinginfo®
Open To Explore®

Outline

- Overview and Background
- Define the study area, identify mappable units, type log, cross sections
- Structure map of Top of A bench
- Log Attribute Analysis
- Production Analysis as it correlates to CW610-CW613 Interval
- Isopach Map Series
- Conclusions

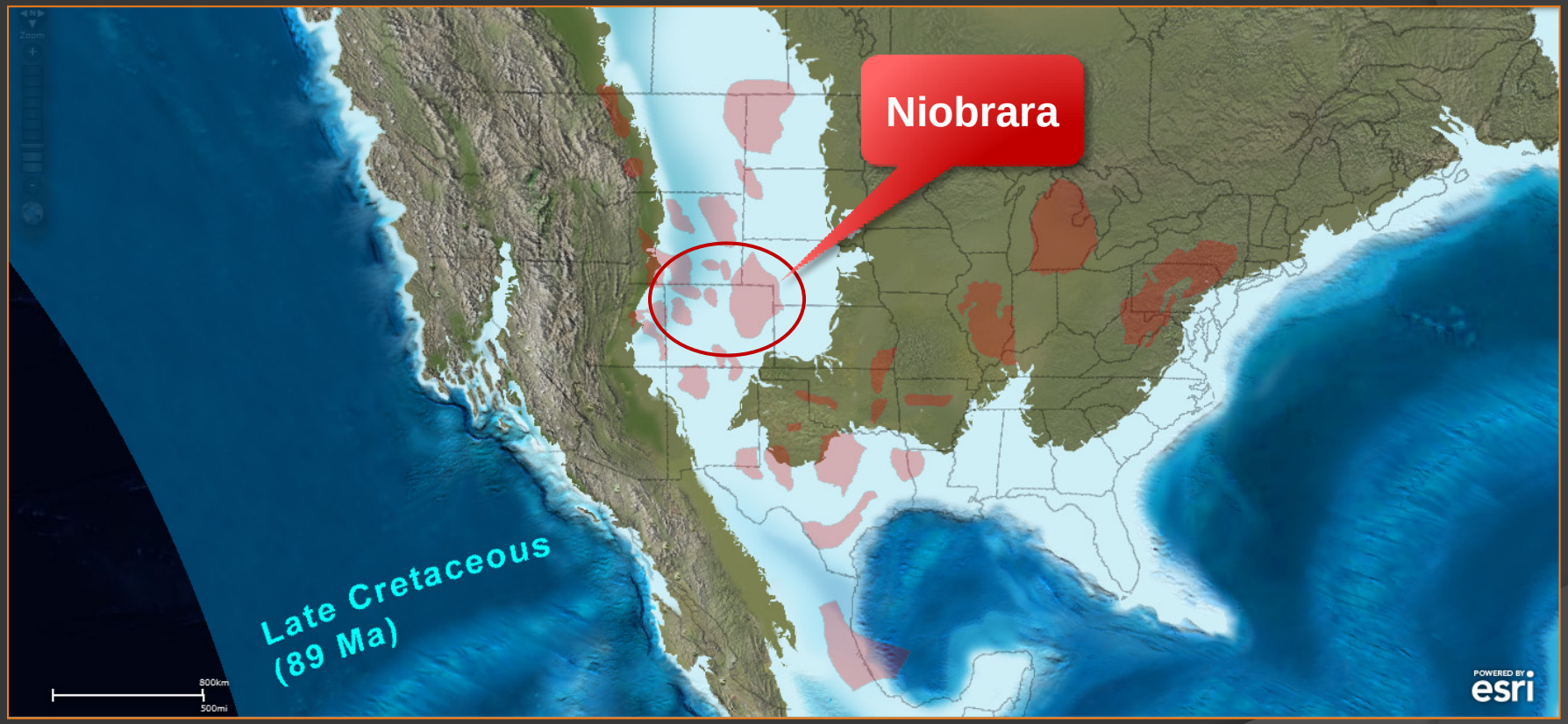
Overview

- Much of the focus on oil and gas production coming out of the Niobrara has been from development of the limestone units in the middle Niobrara, or “B Bench” of the Smoky Hill.
- However, production from the A, C, and Fort Hays chalk intervals in older vertical wells suggest that they may be future targets of horizontal drilling, as well.
- Good well control and an abundance of digital well logs allows for an in-depth look at several distinctive mappable units within the A bench of the Niobrara.

Background

- Niobrara is self-sourced, was deposited 90 mya, submerged in an inland seaway
- warm, tropical waters mixed with cooler water flowing south, combined with fluctuations in sea-level create the alternating layers of inter-bedded chalk and marl, calcareous and organic-rich black shales, and limestones

Late Cretaceous Paleogeography and Western Interior Seaway

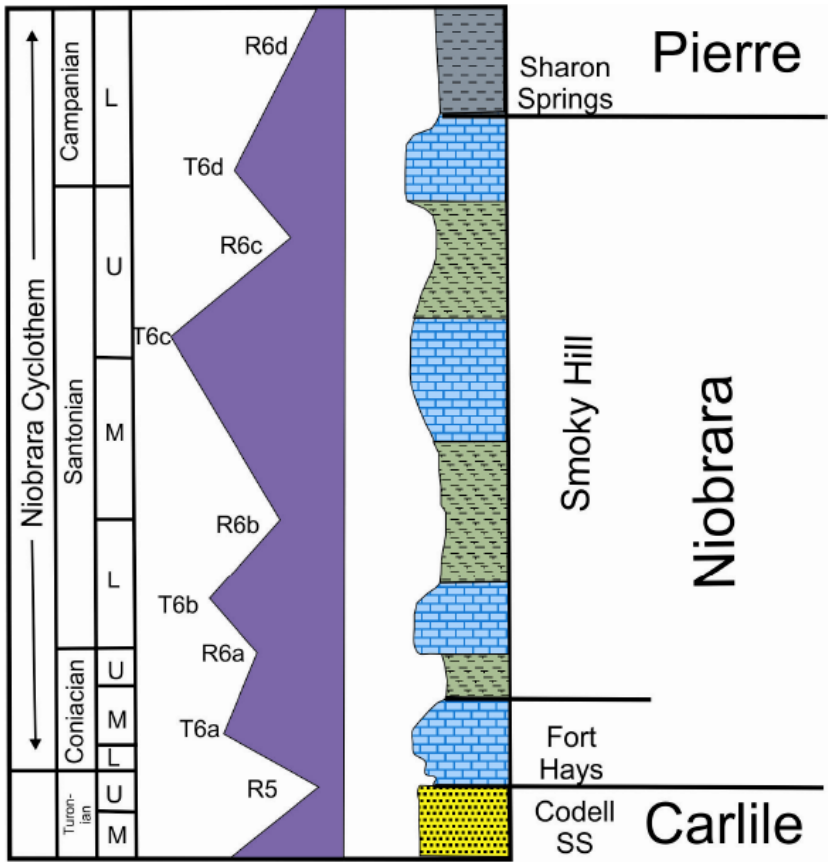


Source: Drillinginfo

Background

- the Niobrara produces in depths from 3,000-14,000 feet with thicknesses ranging from 150 feet on the eastern paleo high to 1,500 feet at the western edge of deposition
- Well depths in the field generally increase from NE to SW
- TOC ranges from 3.2 to 5.8 % in source beds
- <0.1 - 3 permeability (md)
- 8 -10% porosity
- Niobrara fracs well; natural fractures are locally abundant
- 80-90% carbonate

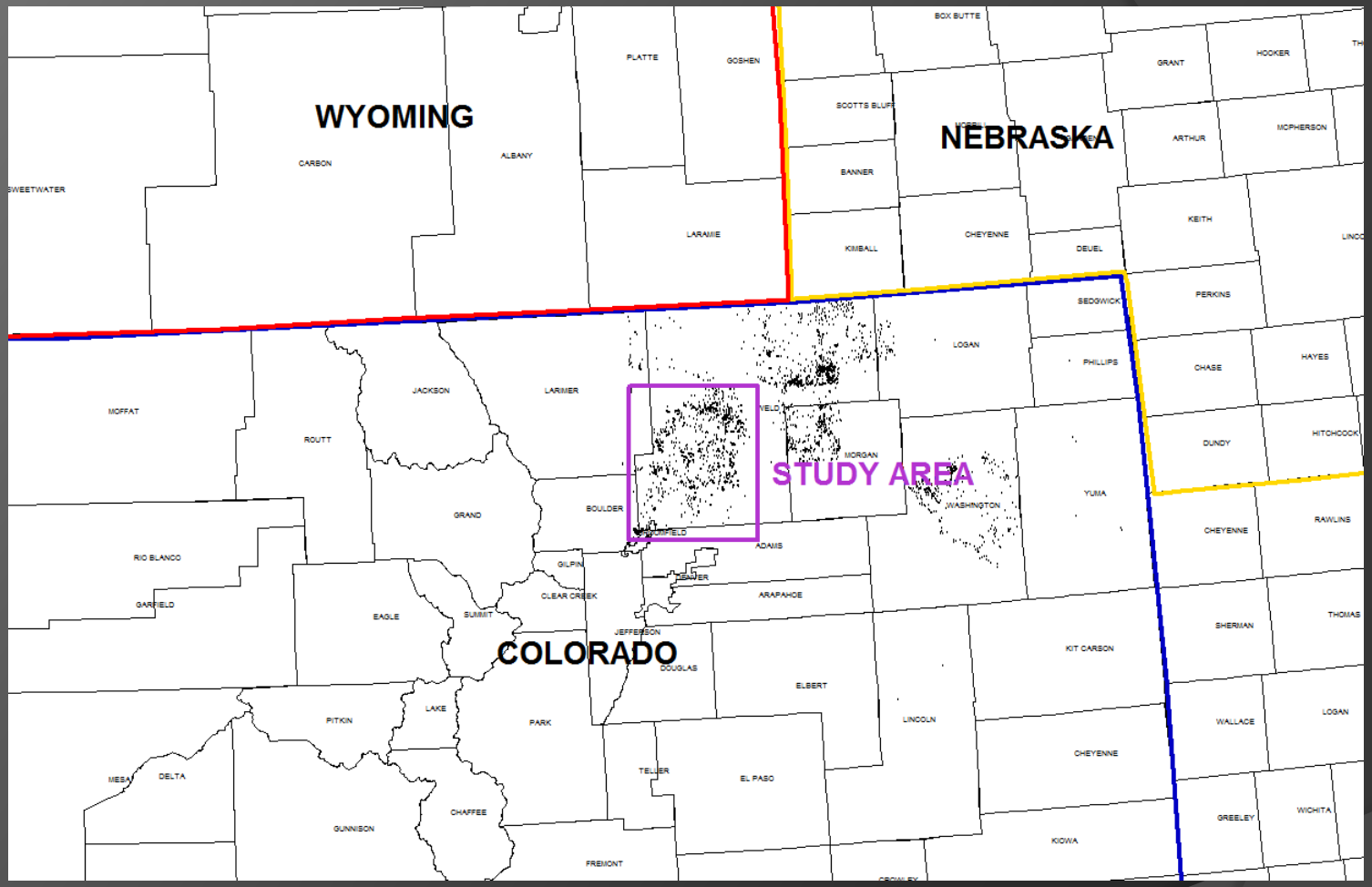
Niobrara Stratigraphy



Modified from Longman et al., 1998, after Barlow, 1986

Source: Sonnenburg, 2010

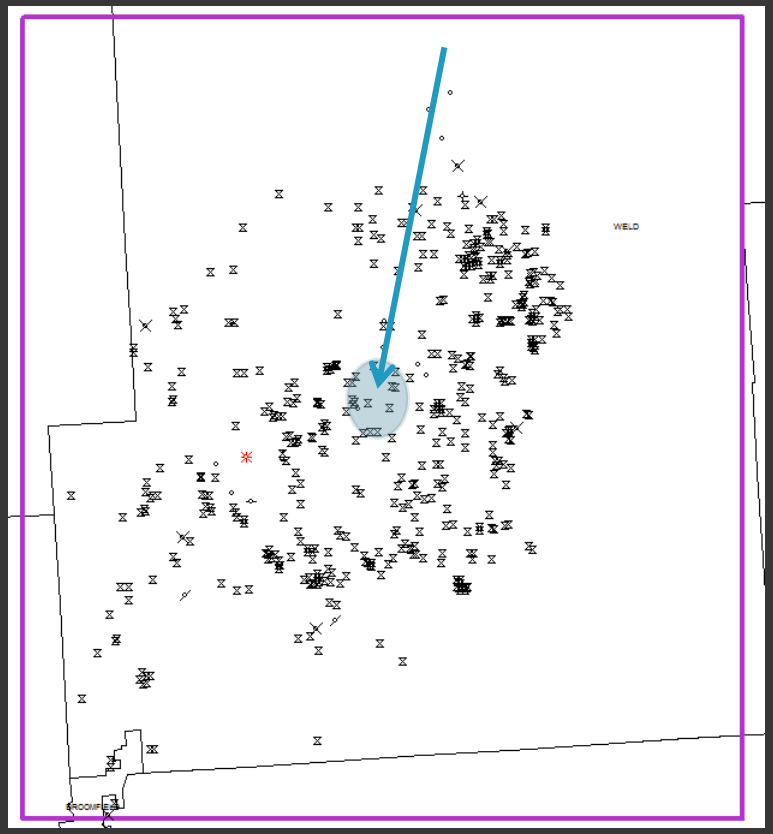
Base Map of the Study Area



- Focus was primarily in SW corner of Weld county, CO
- Have over 5000 wells in the Wattenberg field area in our database
- Used 517 wells with logs in our analysis (study area)

Type Log

Atreyu F 34-23, Noble Energy



- Near center of field
- Drilled in 2007
- Contains well defined examples of all seven distinctive units we identified in our study

Niobrara A Bench

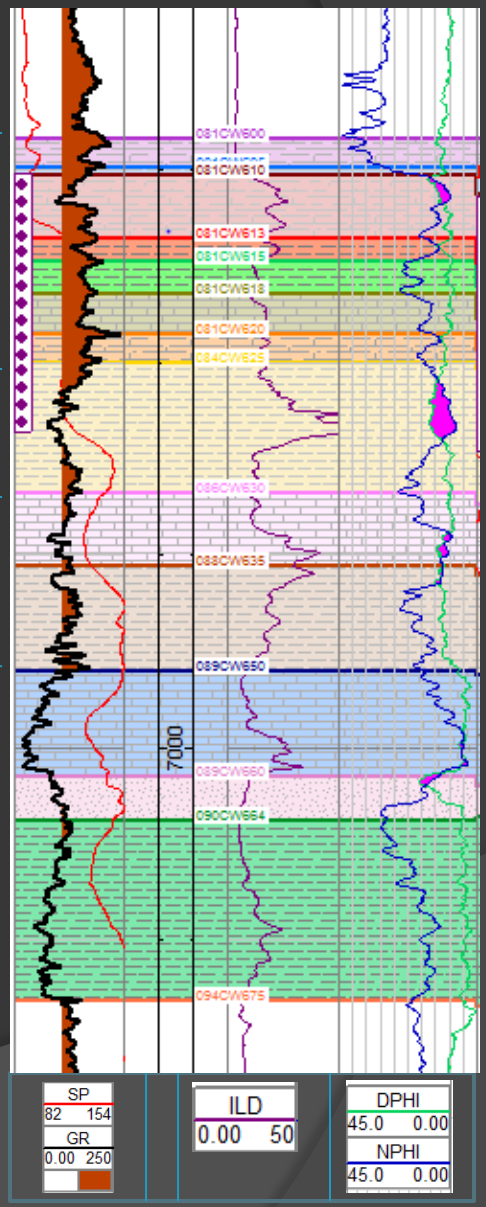
Niobrara B Bench

Niobrara C Bench

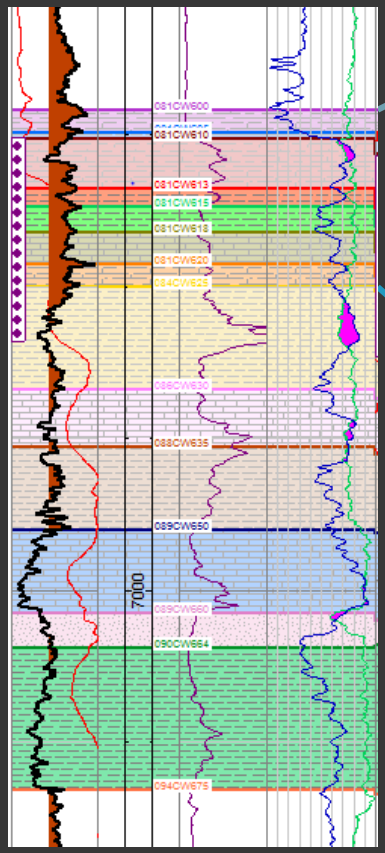
Fort Hays Limestone

Codell Sandstone

Carlile Shale

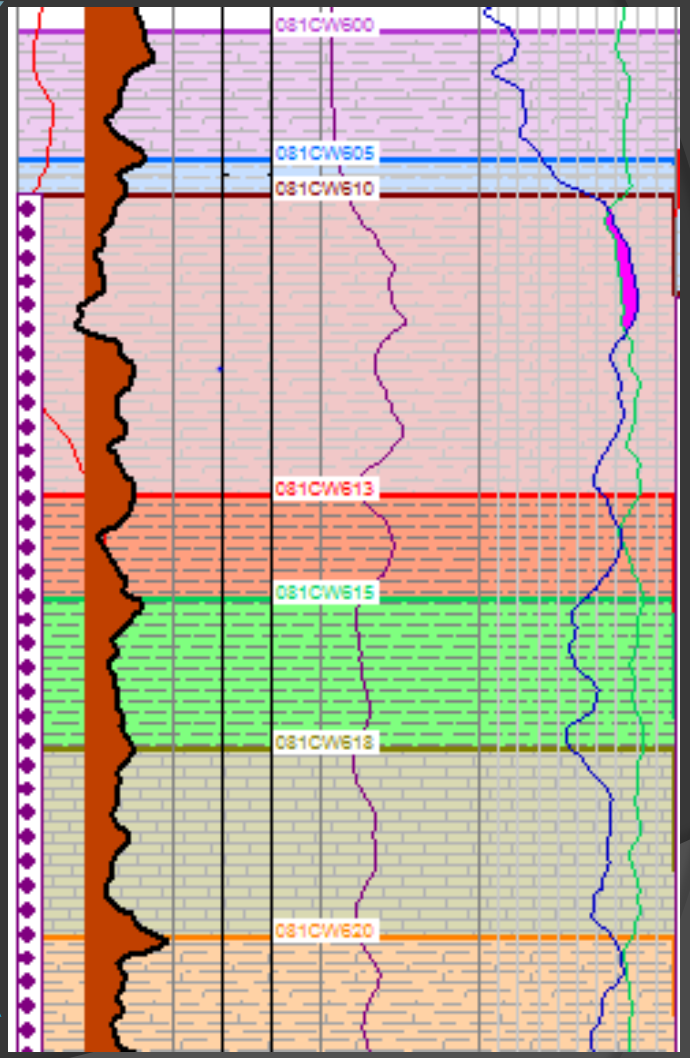


Detailed Study Zone



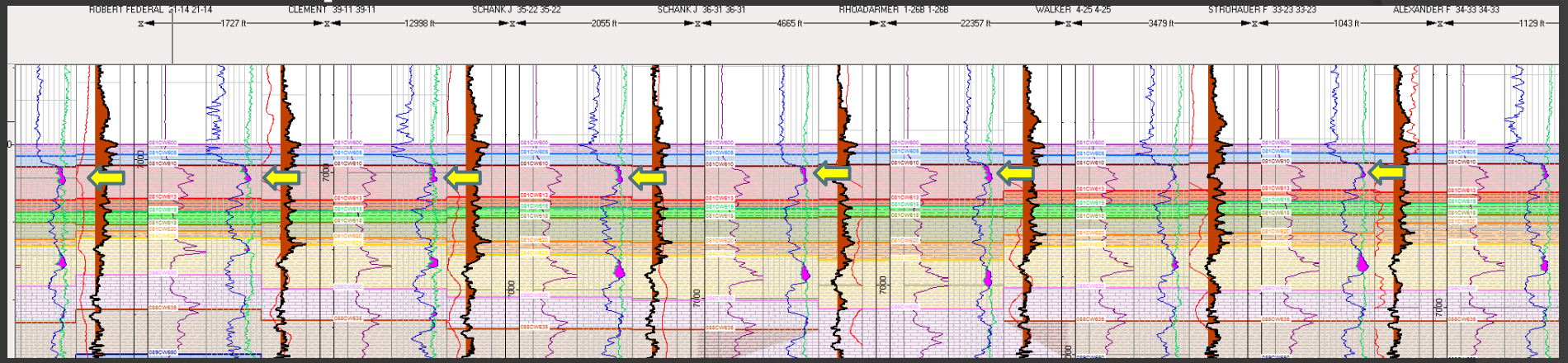
Niobrara A Bench

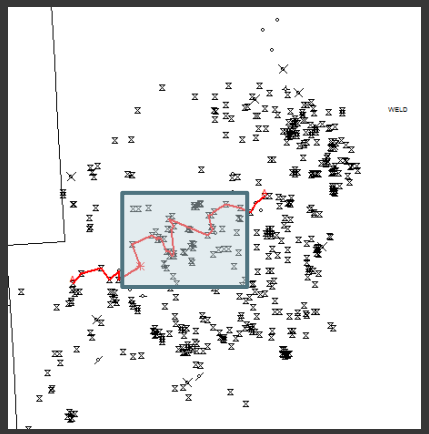
Seven Distinctive Mappable Units



Our correlations based solely on log character: no cores, cuttings or seismic used in interpretation

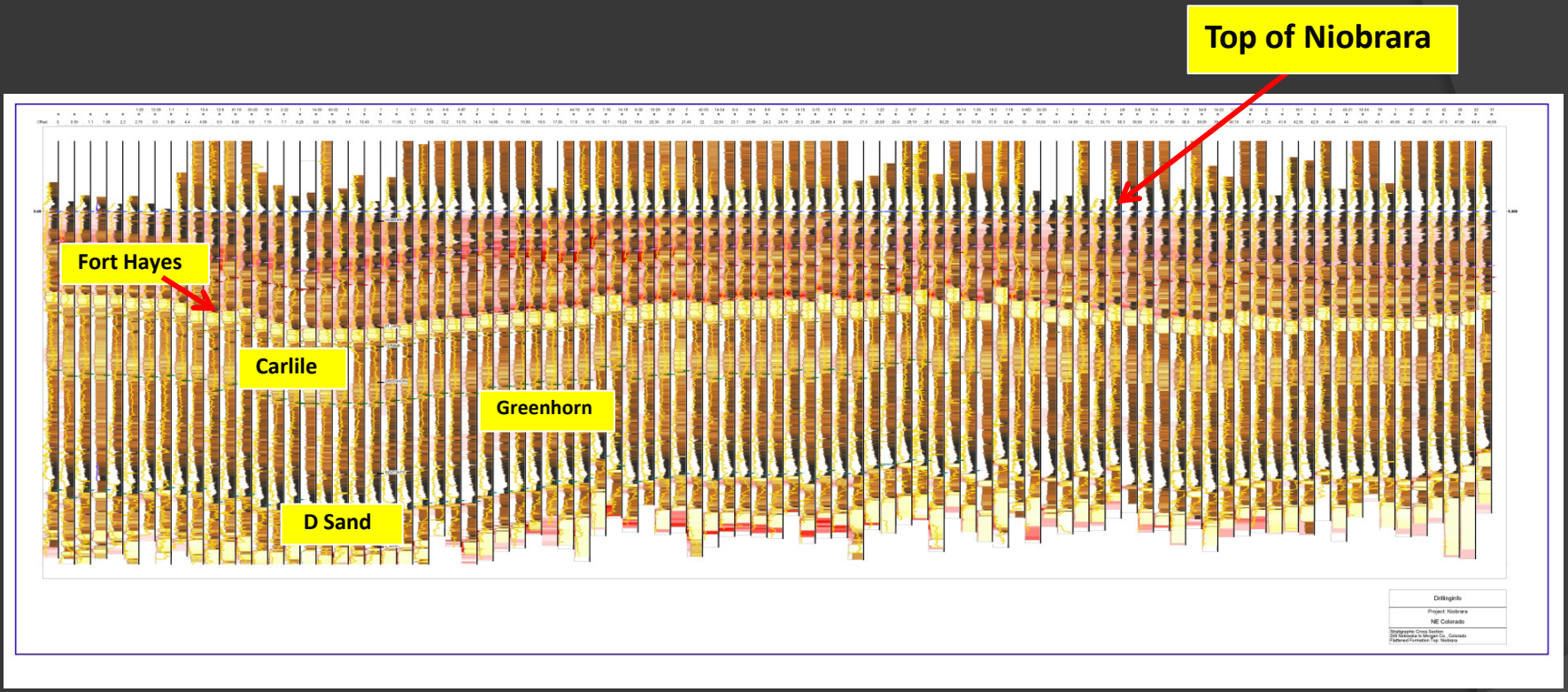
Example Cross Section





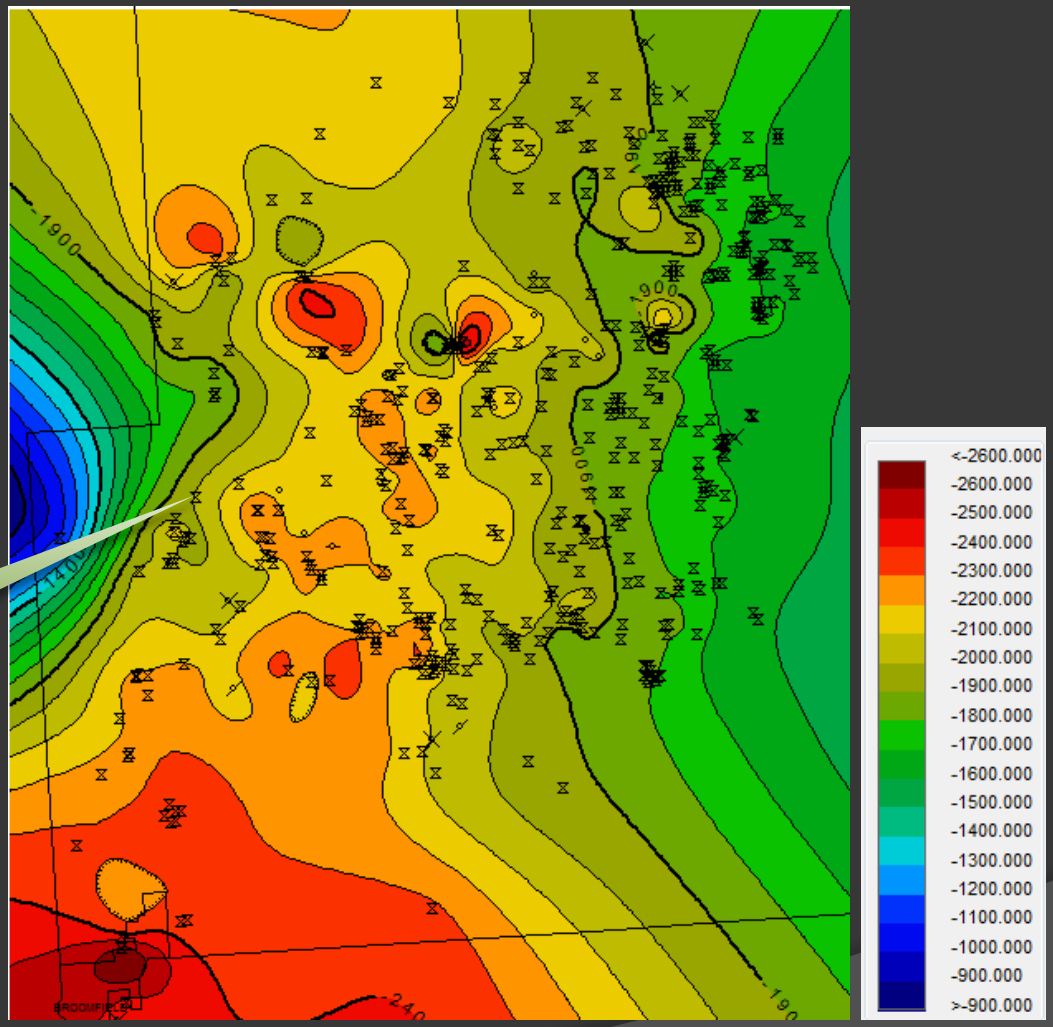
- The dark blue curve (NPHI) is an indicator of liquid filled porosity. The green curve (DPHI) is an indicator of bulk density. The presence of gas (light HC) in the pore space causes DPHI to be more than the actual porosity.
- This creates a ”cross-over” effect in the log response, which is a known indicator of hydrocarbons present. This effect is highlighted in pink and denoted by the yellow arrows. The zone is the CW610-CW613.

EarthSLICE Cross Section



- Correlations made on a regional basis using high density cross sections
- 60+ wells displayed here, W to E
- Type of display similar to seismic interpretation
- Used to easily identify major flooding surfaces and formations

Structure Map – A Bench

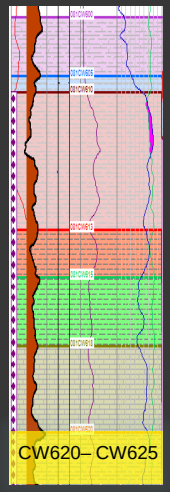


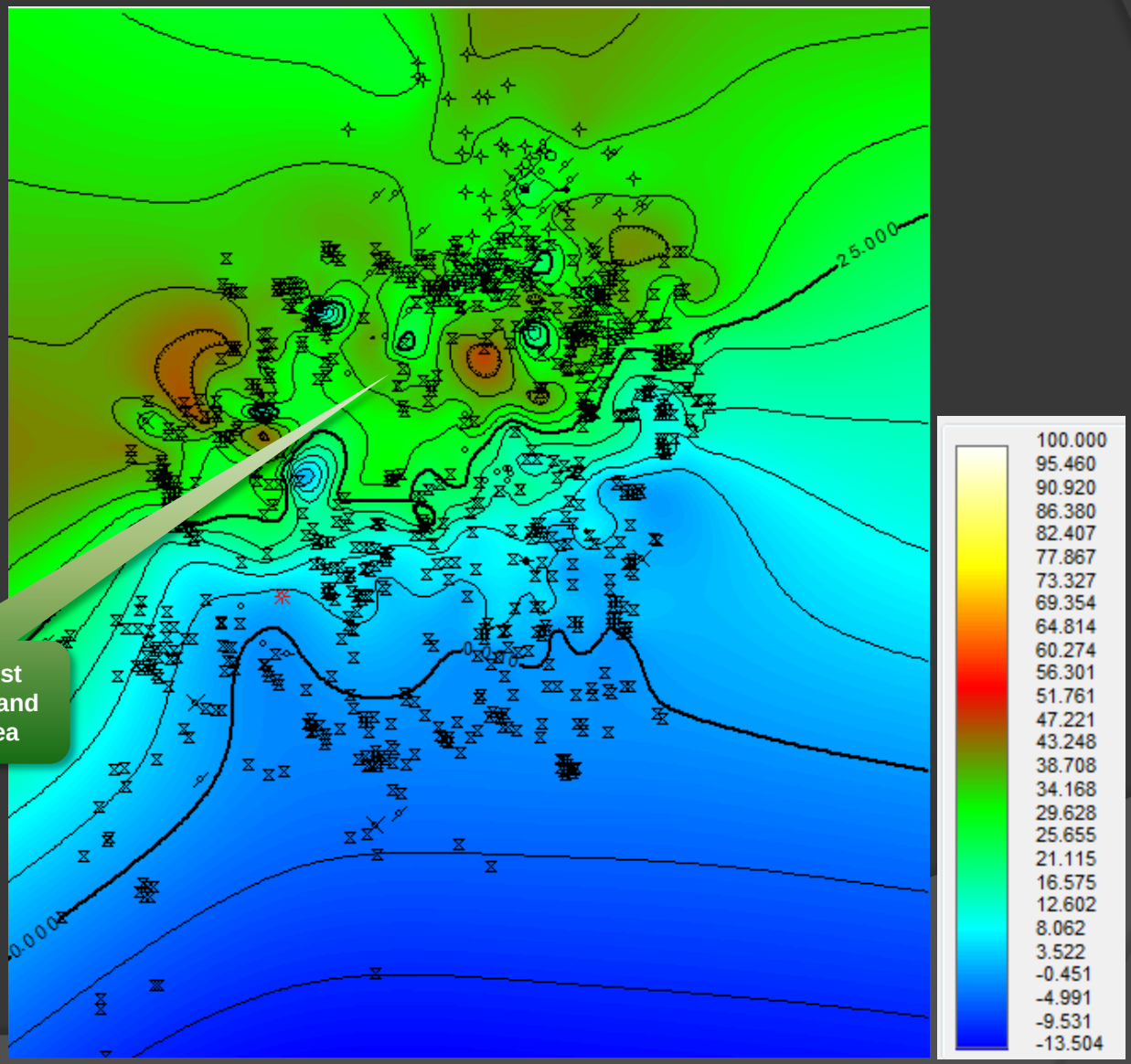
Evidence of Southwest plunging axis of the Denver Julesburg Basin

Log Attribute Analysis

- Using log data for the study area, we were able to systematically process log attributes for each of the seven intervals identified in the “A” bench. These include the following:
- Isopach Thickness maps for each interval
- Contour maps using the arithmetic mean for average responses for
  - ILD (Deep Induction)
  - SP
  - GR
  - NPHI for each interval
- Density crossover thickness contour for the CW610-CW613 interval – hydrocarbon target area

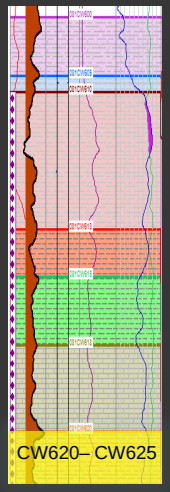
Isopach Thickness Map of CW620-CW625



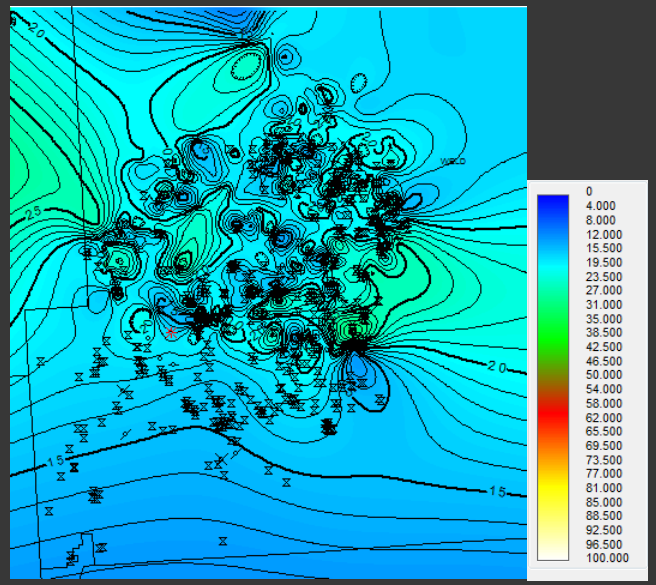


Deposition thickest towards the North and Central Study Area

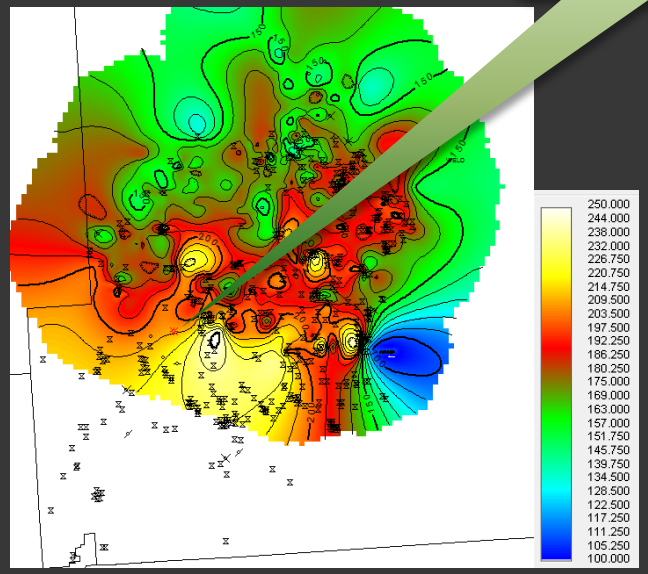
Log Attribute Analysis – CW620 – CW625



NPHI

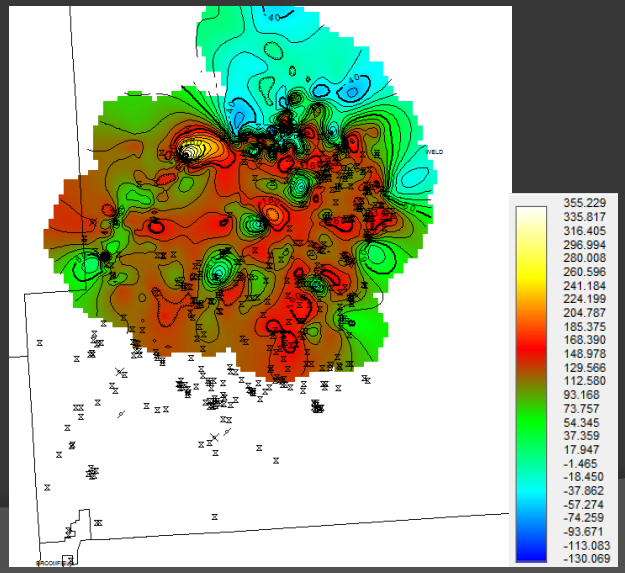


Gamma Ray

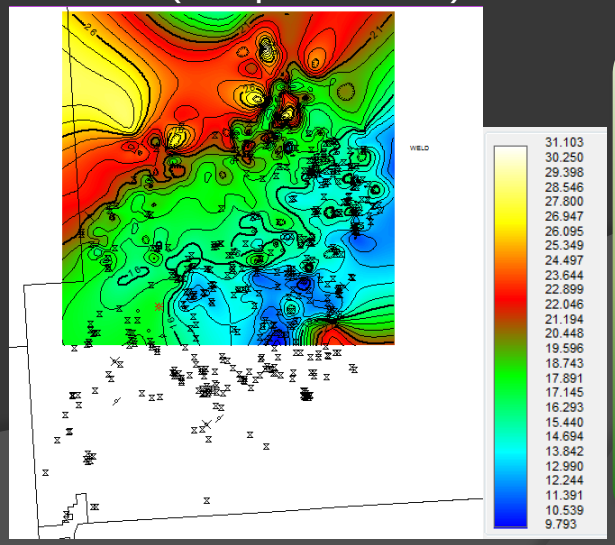


Averages higher in SW corner: sand deposition from North

SP

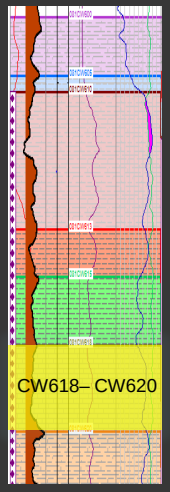


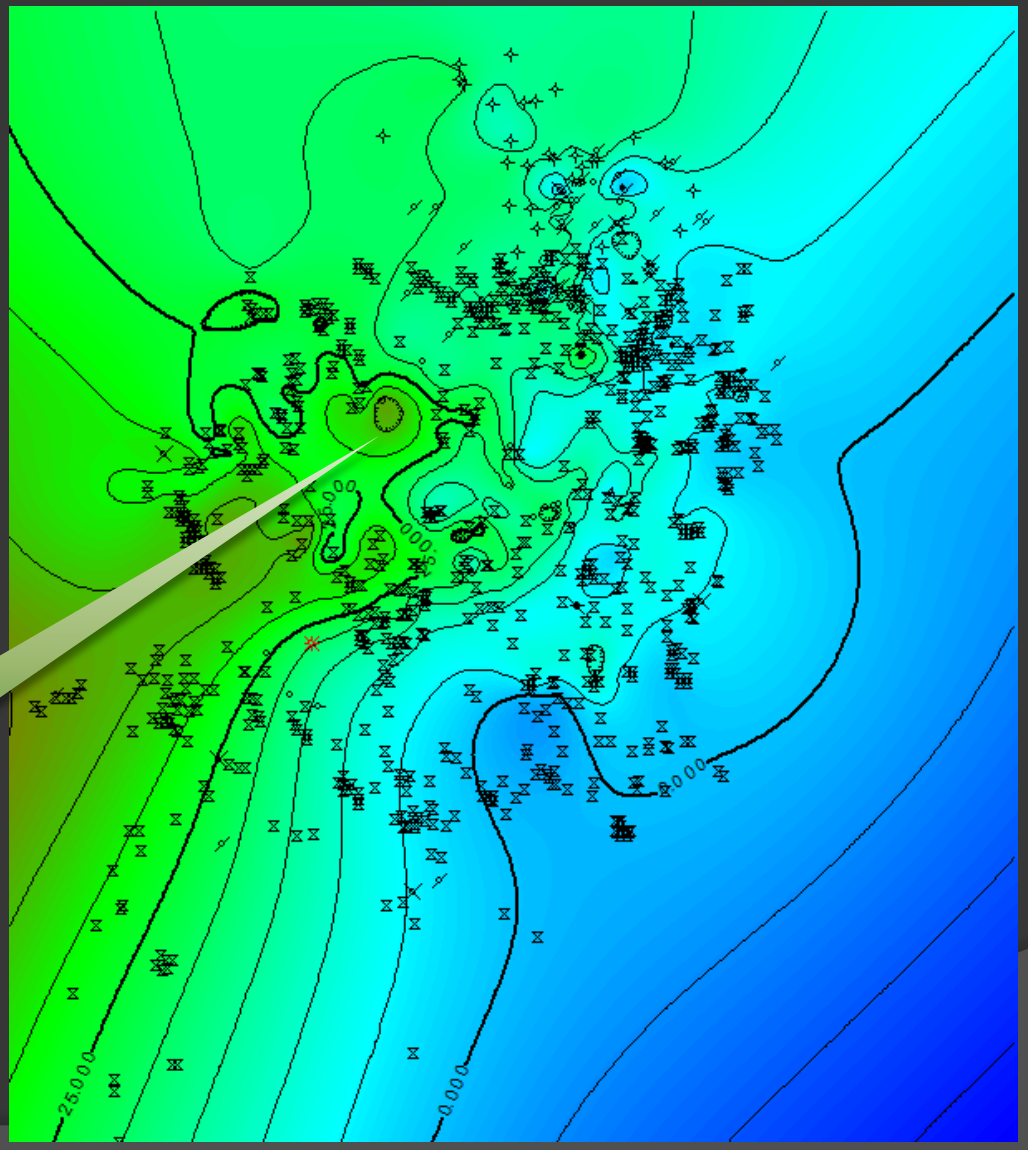
ILD (Deep Induction)

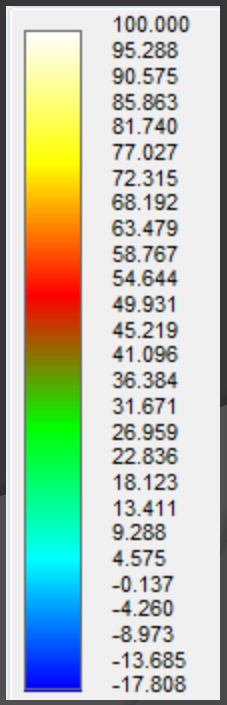


Response is strong in NW, higher resistivities, trending lower southeast. Could indicate a shoreline feature such as a calcite cemented limestone bank

Isopach Thickness Map of CW618-CW620



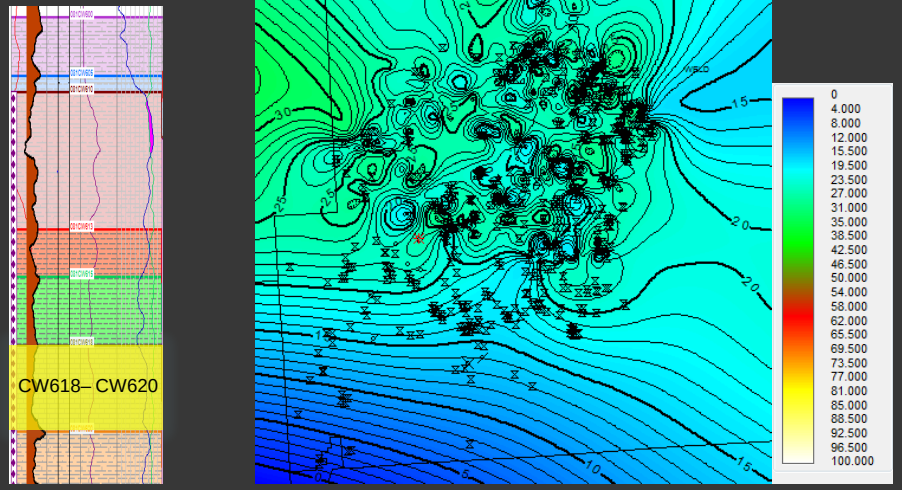




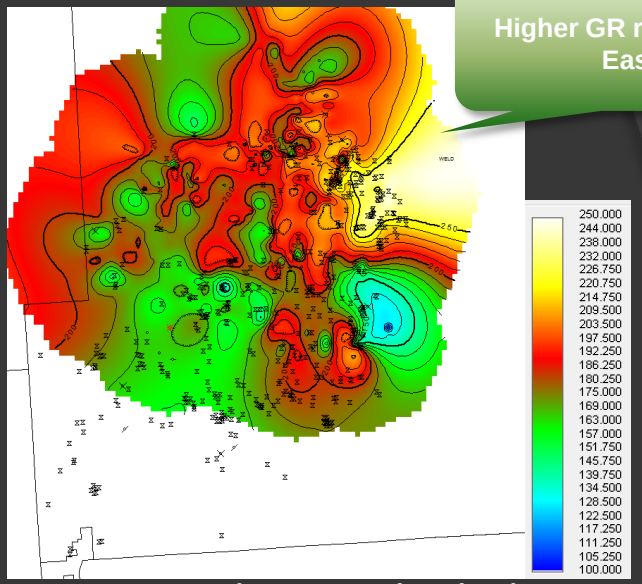
Deposition thickest towards the West and appears to be moving southward

Log Attribute Analysis – CW618 – CW620

NPHI

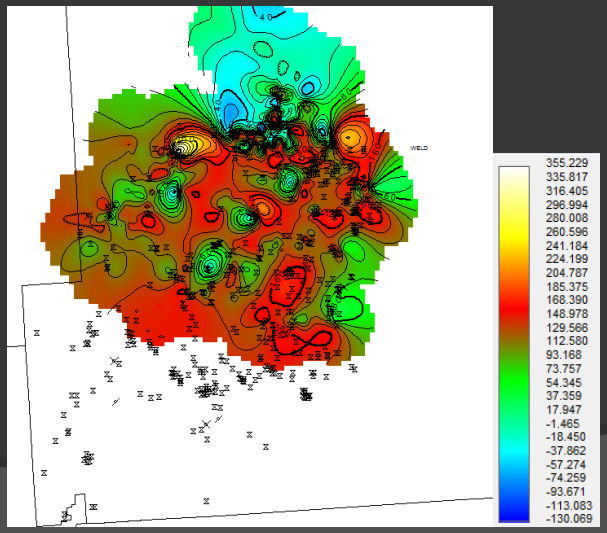


Gamma Ray

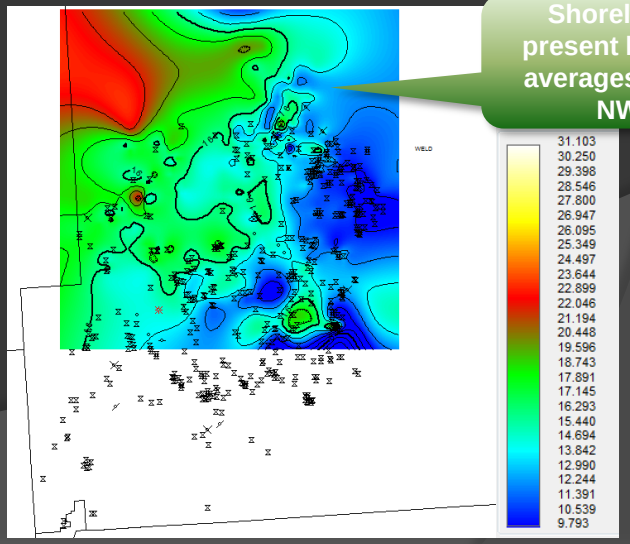


Higher GR responses East

SP

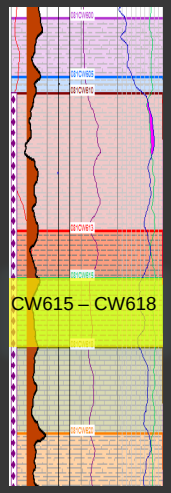


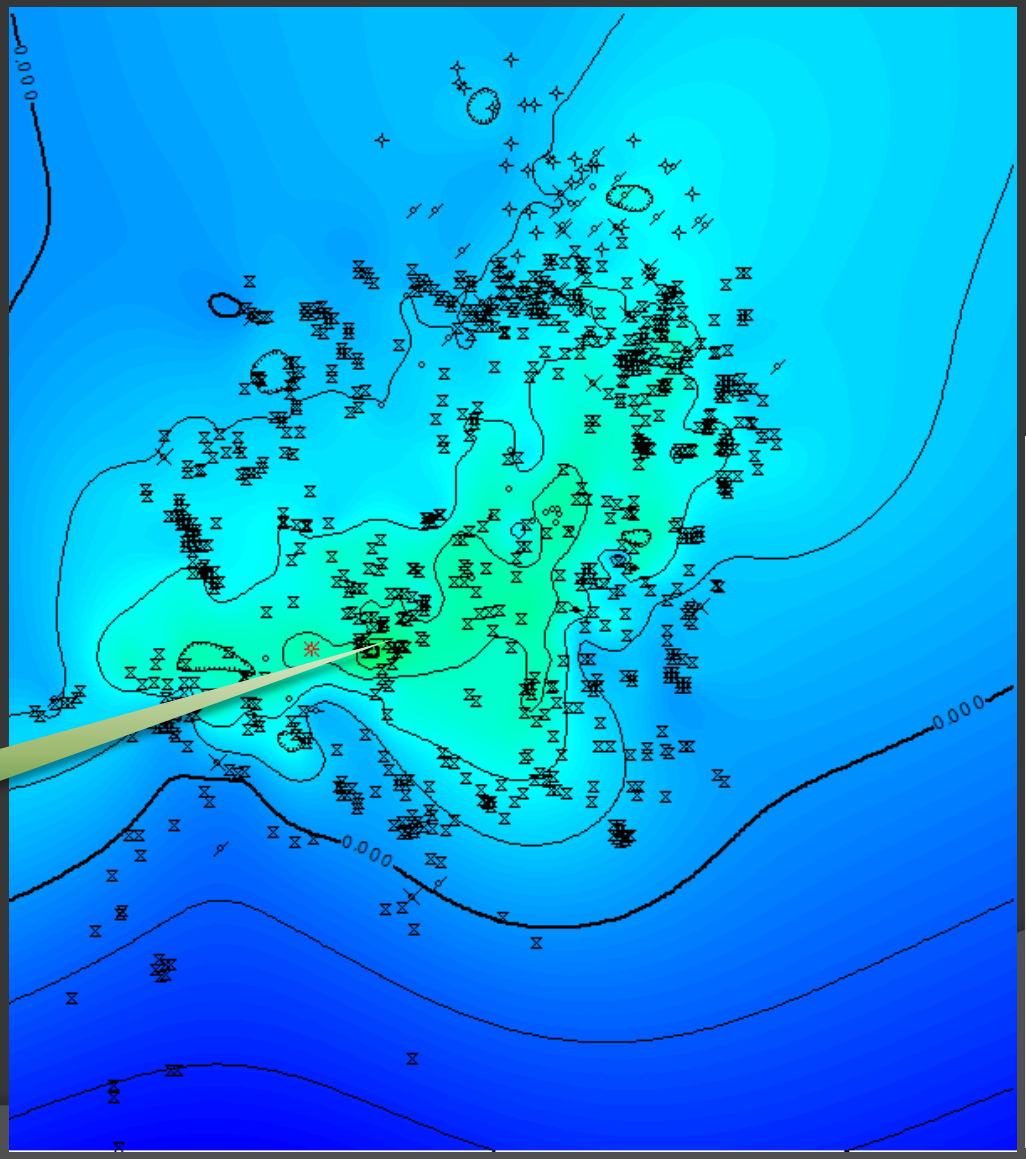
ILD (Deep Induction)

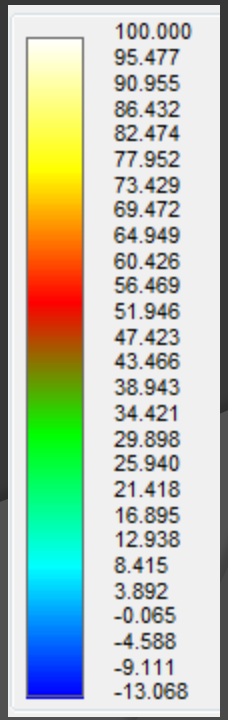


Shoreline feature present here, as well, averages trend lower NW to SE

Isopach Thickness Map of CW615-CW618



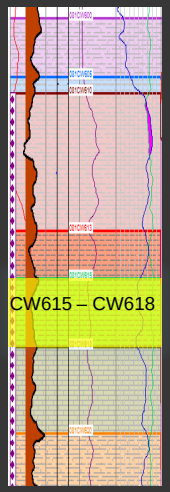


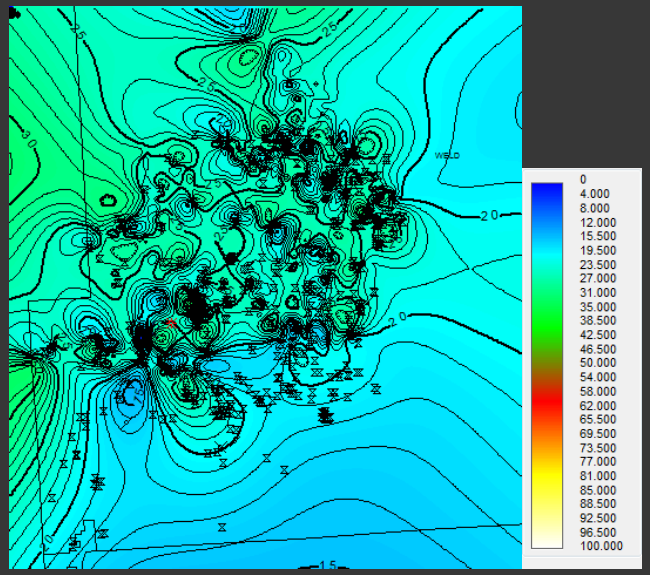


Deposition continues moving southward, thickest near the center

Log Attribute Analysis – CW615 – CW618

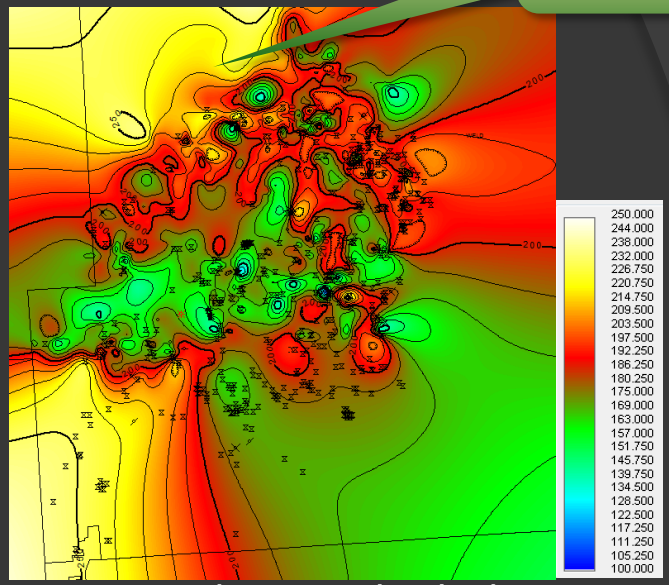
NPHI



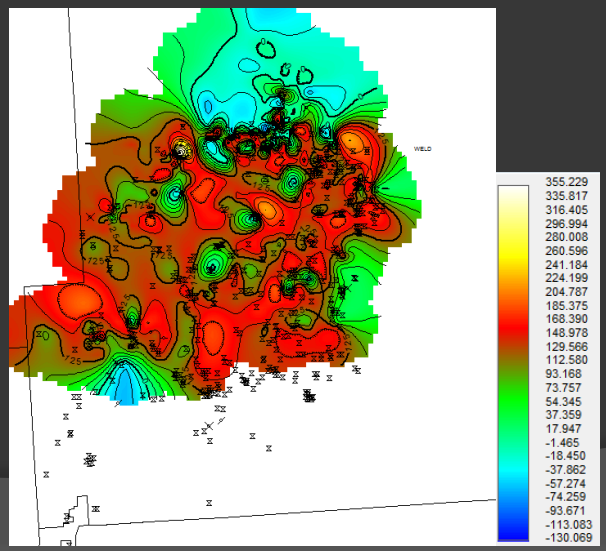


Gamma Ray

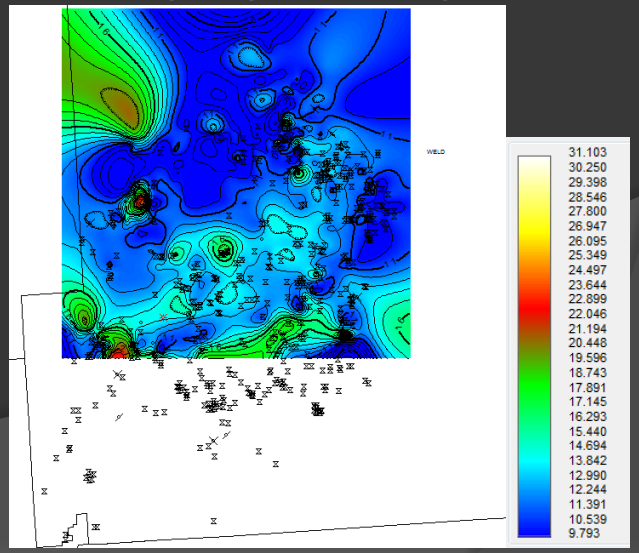
GR responses are highest in the West, trending SE



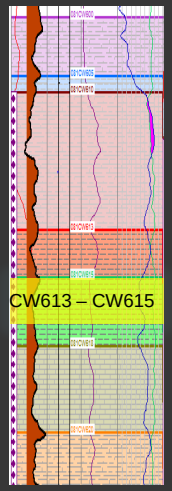
SP

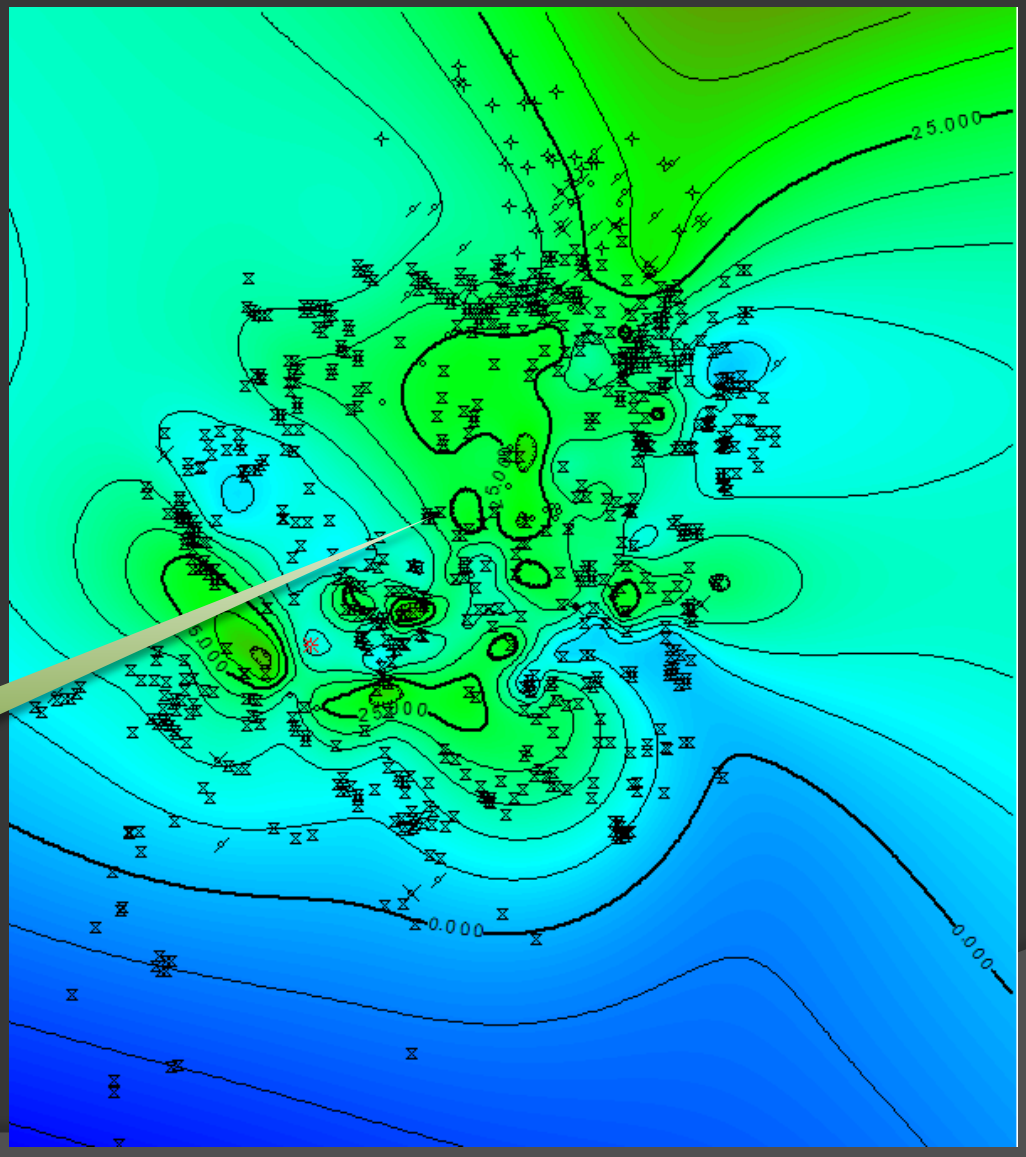


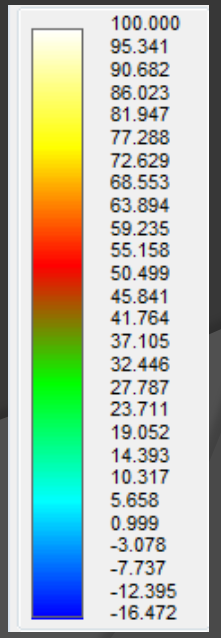
ILD (Deep Induction)



Isopach Thickness Map of CW613-CW615



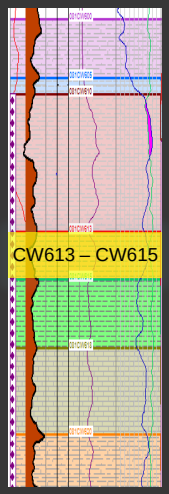


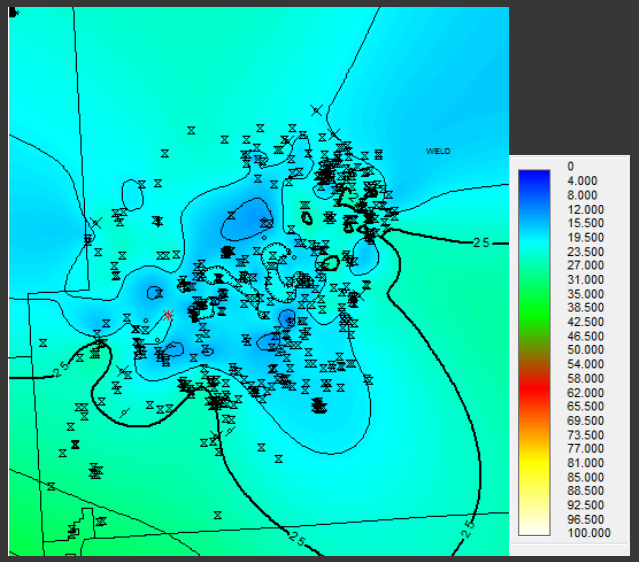


Deposition building near center of field, indicator of possible stacking in place

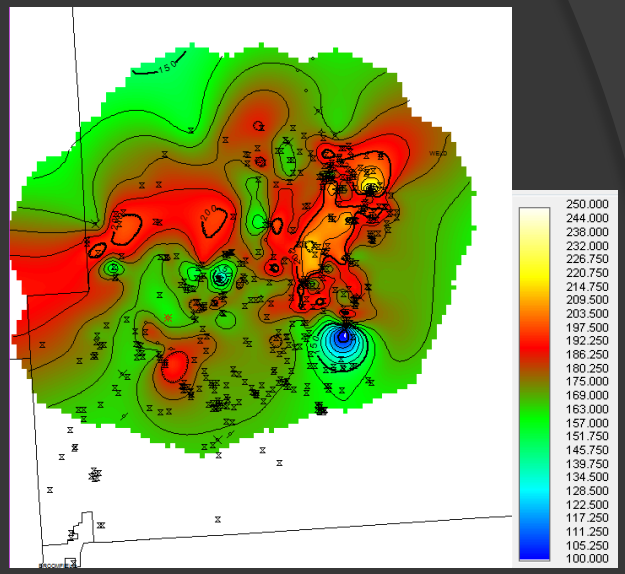
Log Attribute Analysis – CW613 – CW615

NPHI

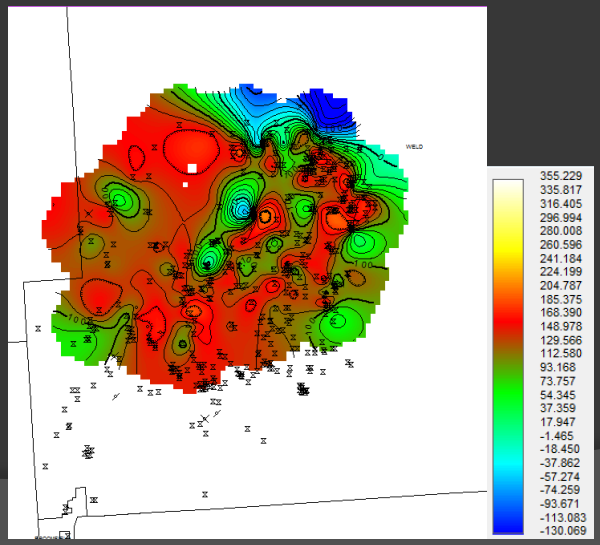




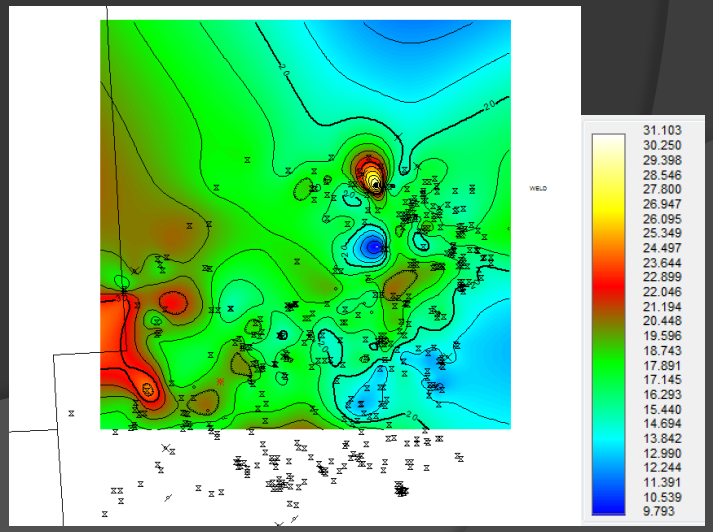
Gamma Ray



SP



ILD (Deep Induction)

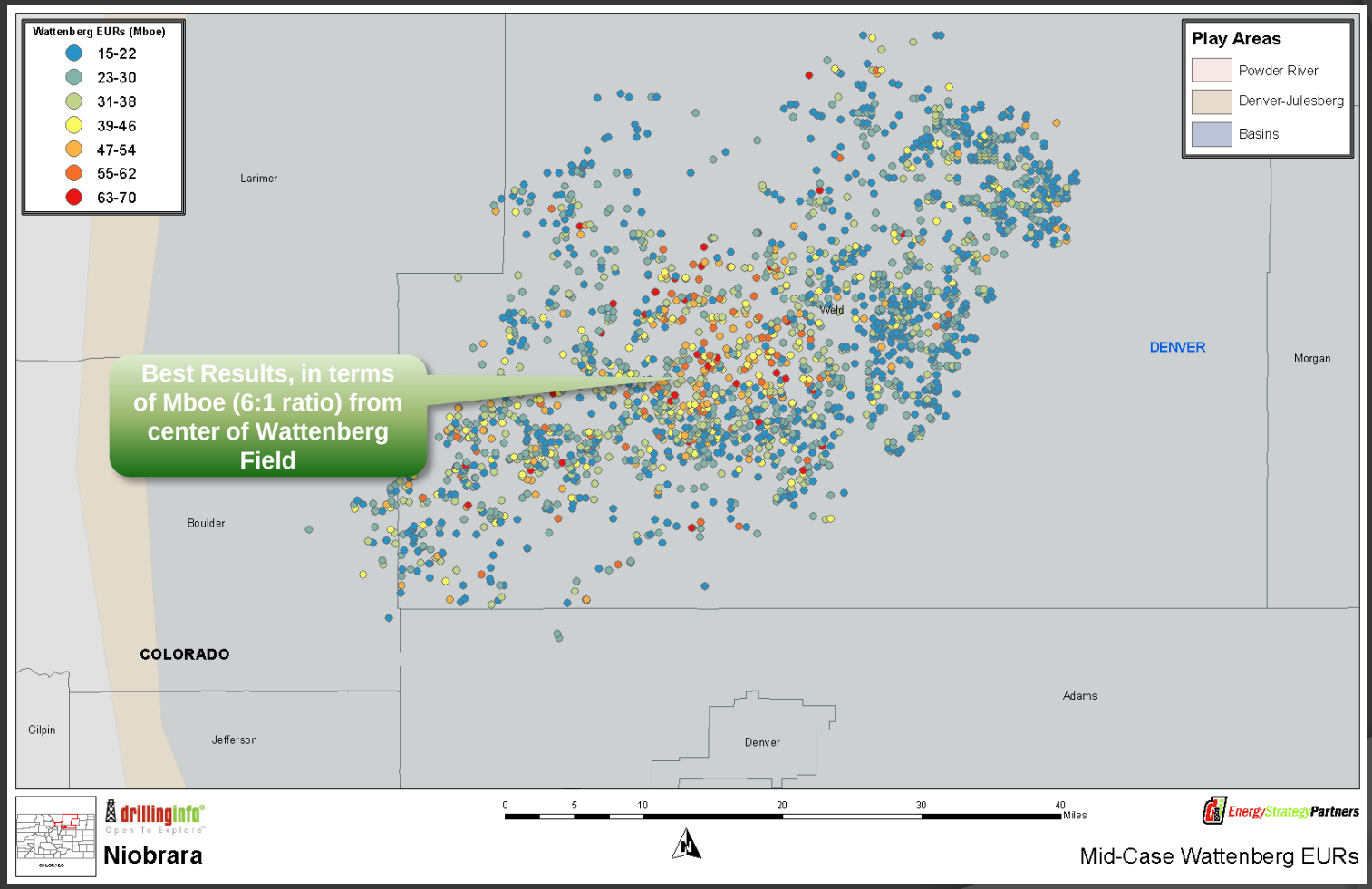


Top US Fields by Cumulative Production

RANK	FIELD	STATE	First Production	CUM LIQUIDS (MMBBL)	CUM GAS (BCF)	CUM (MMBOE)	WELL COUNT
1	PRUDHOE BAY	AK	4/1/1969	12,126	67,530	23,382	3,208
2	SAN JUAN BASIN AREA	CO / NM	1/1/1951	52	36,906	6,203	23,887
3	KUPARUK RIVER	AK	4/1/1970	2,413	3,171	2,941	1,720
4	PANHANDLE, WEST	TX	1/1/1941	0	14,259	2,377	5,231
5	WASSON	TX	1/1/1939	1,804	3,043	2,311	4,958
6	CARTHAGE	TX	1/1/1942	59	10,793	1,857	7,264
7	EAST TEXAS	TX	1/1/1955	1,655	530	1,743	7,836
8	ELK HILLS	CA	1/1/1977	1,022	4,059	1,698	5,356
9	MIDWAY-SUNSET	CA	1/1/1977	1,680	79	1,694	32,152
10	SPRABERRY	TX	1/1/1938	1,129	2,953	1,621	21,399
23	**WATTENBERG**	**CO**	**12/1/1951**	**276**	**3,837**	**915**	**27,224**

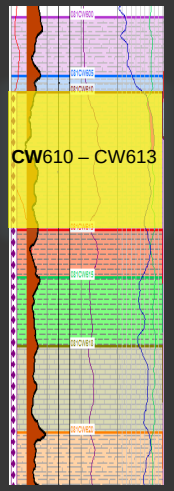
Note: DI-ESP data set. San Juan Basin Area includes Basin, Blanco and Ignacio Blanco Fields. BOE Conversion – 6:1.

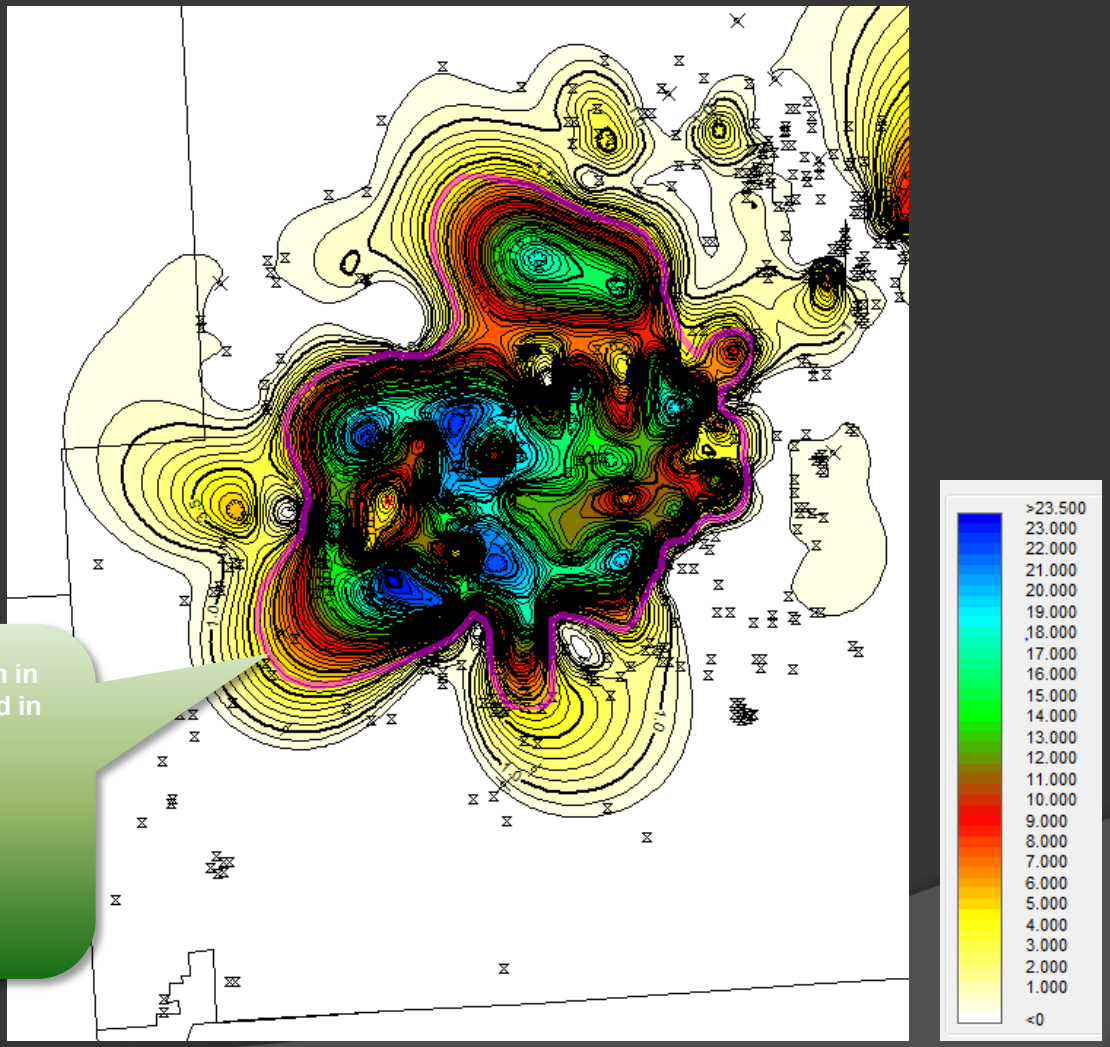
Wattenberg EURs



Source: DI ESP Dataset as of January 2012. Powered By Value Navigator

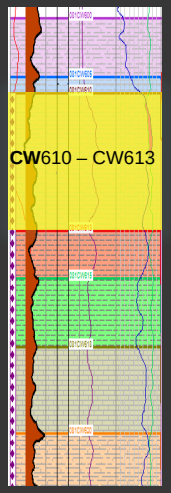
NPHI/DHPI Cross Over Thickness Map CW610-CW613 Interval

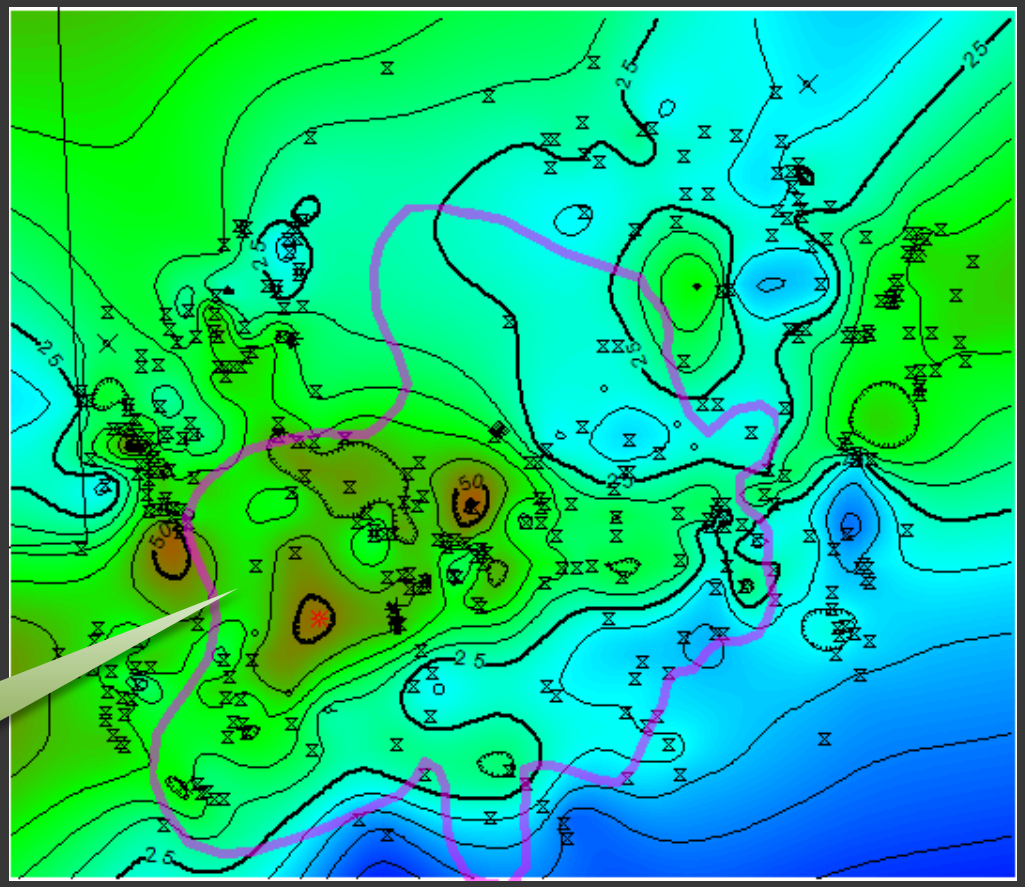


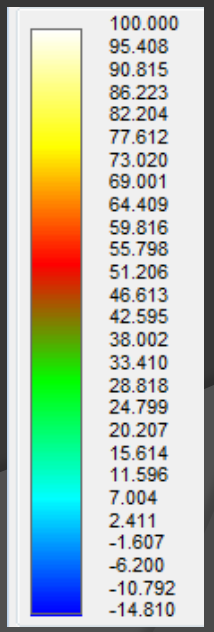


- outline of crossover area as seen in subsequent slides and discussed in example cross section
- The thickest zones are shown in blue, and correlate well with the highest projected EUR's on the previous slide.

Isopach Thickness Map of CW610-CW613



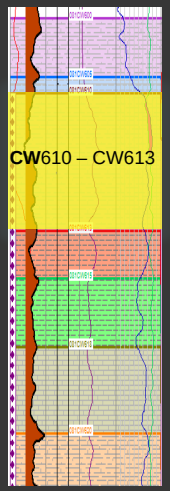


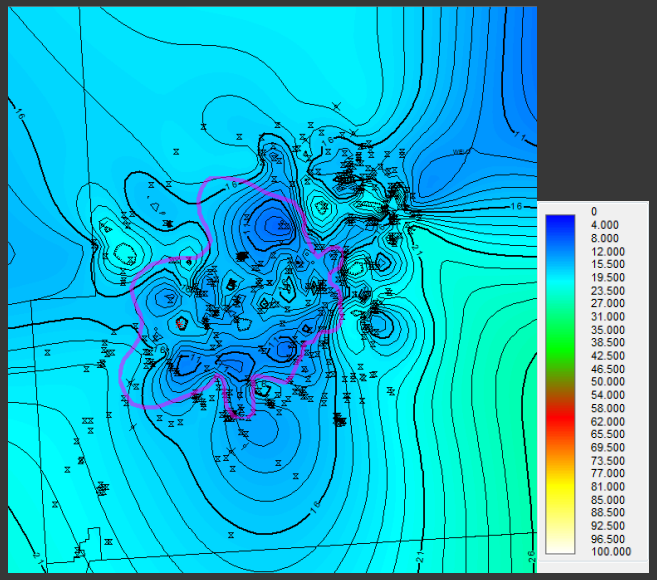


Deposition occurred during a high-stand event; significant sea-level rise. Retrograde thickness throughout.

Log Attribute Analysis – CW610 – CW613

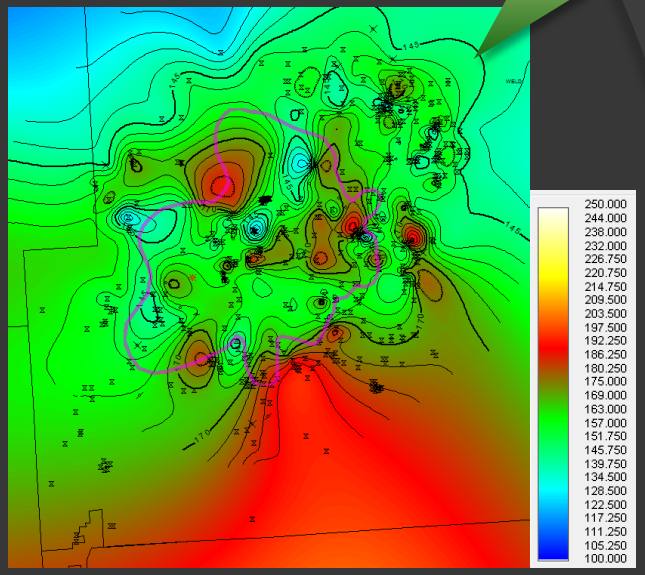
NPHI



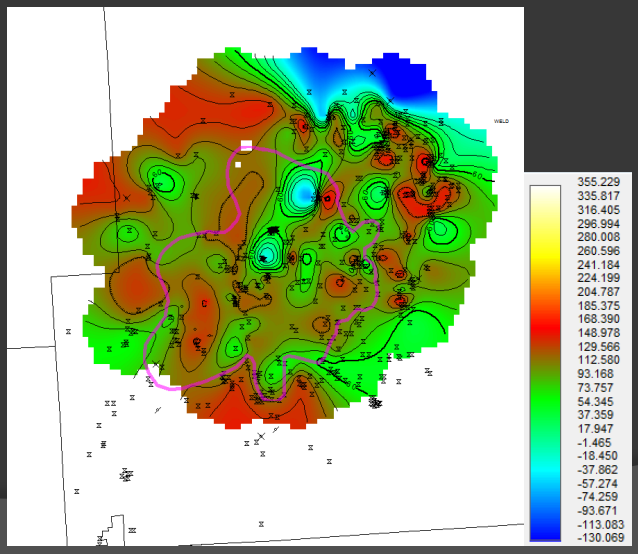


Gamma Ray

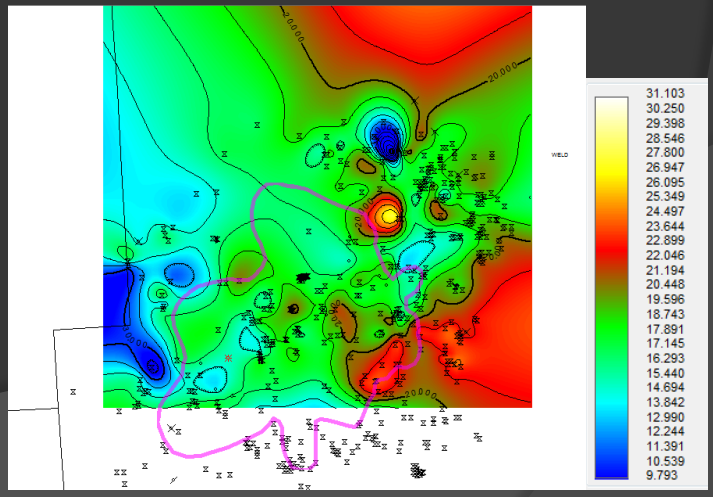
Lower average GR: ties loosely with EUR's



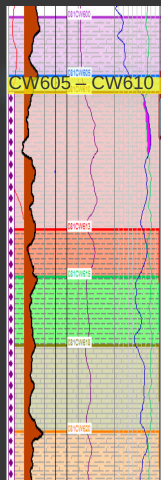
SP

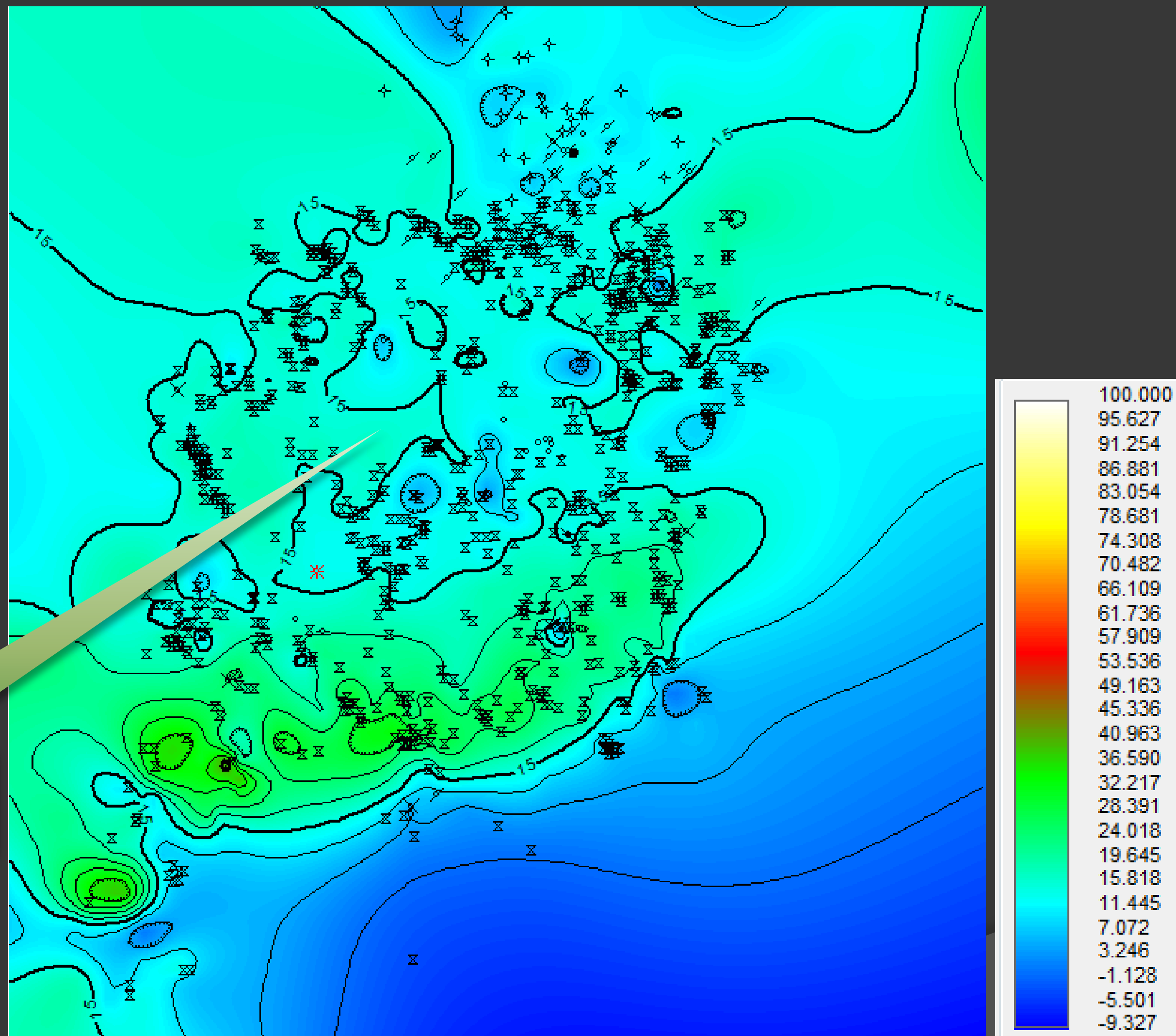


ILD (Deep Induction)



Isopach Thickness Map of CW605-CW610

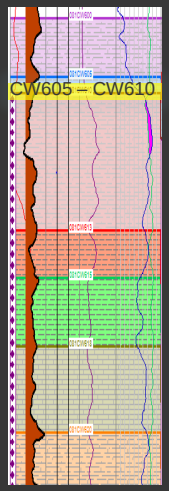




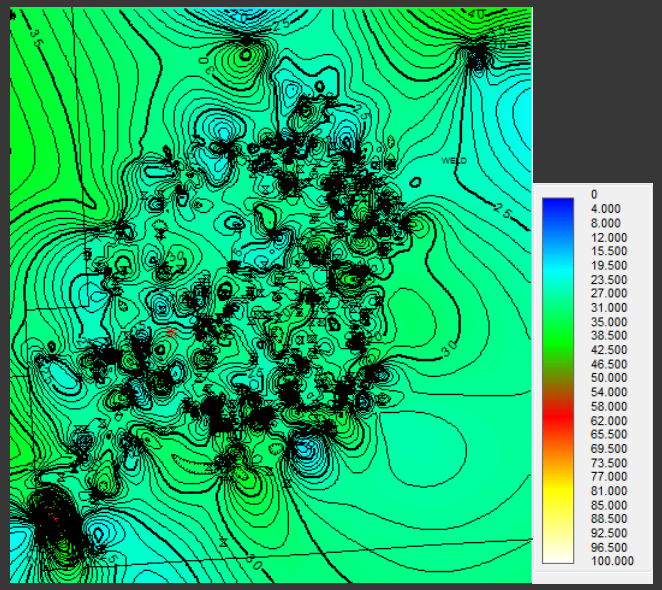
More regression as thickest sections are moving southward

Log Attribute Analysis – CW605 – CW610

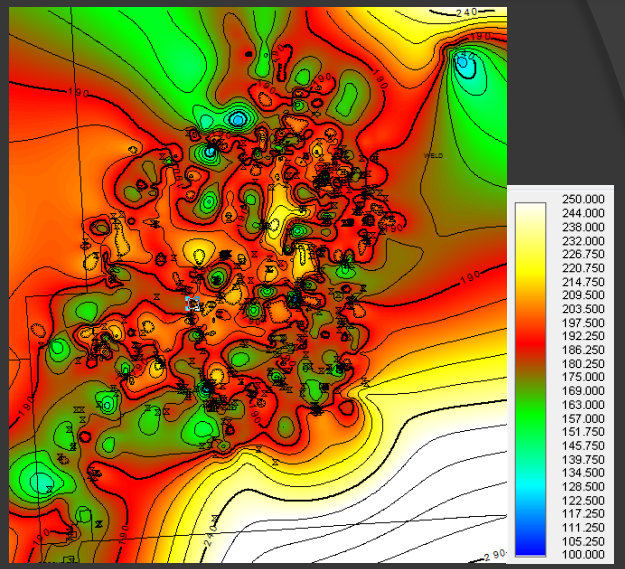
Unit is relatively thin: log responses are highly variable



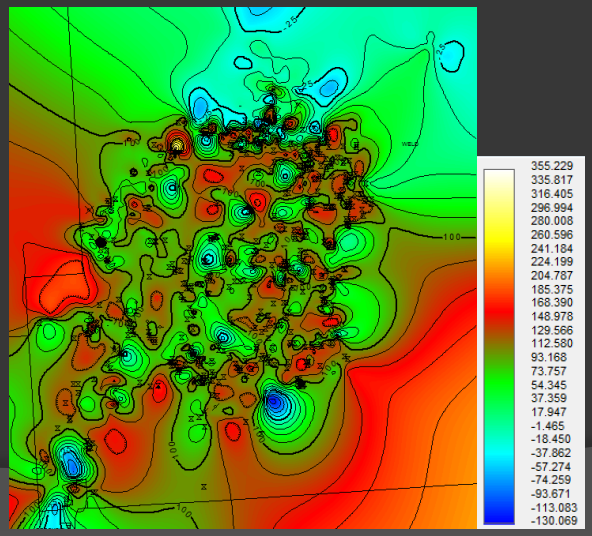
NPHI



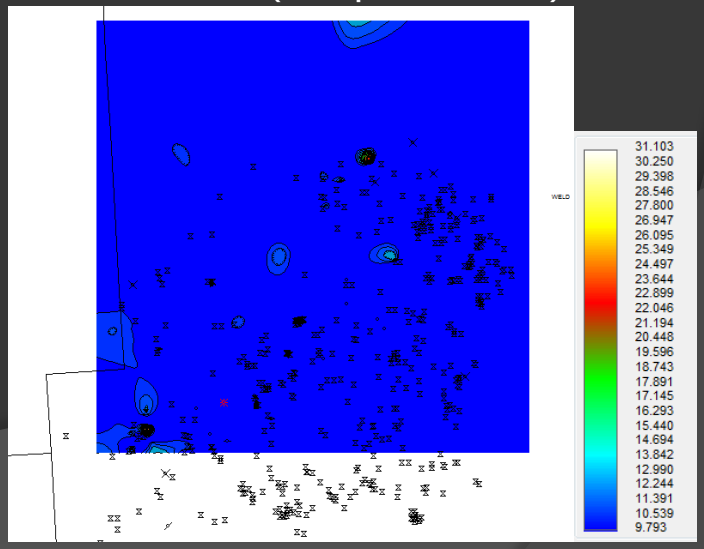
Gamma Ray



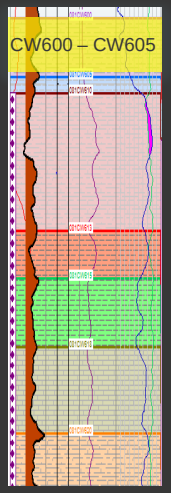
SP

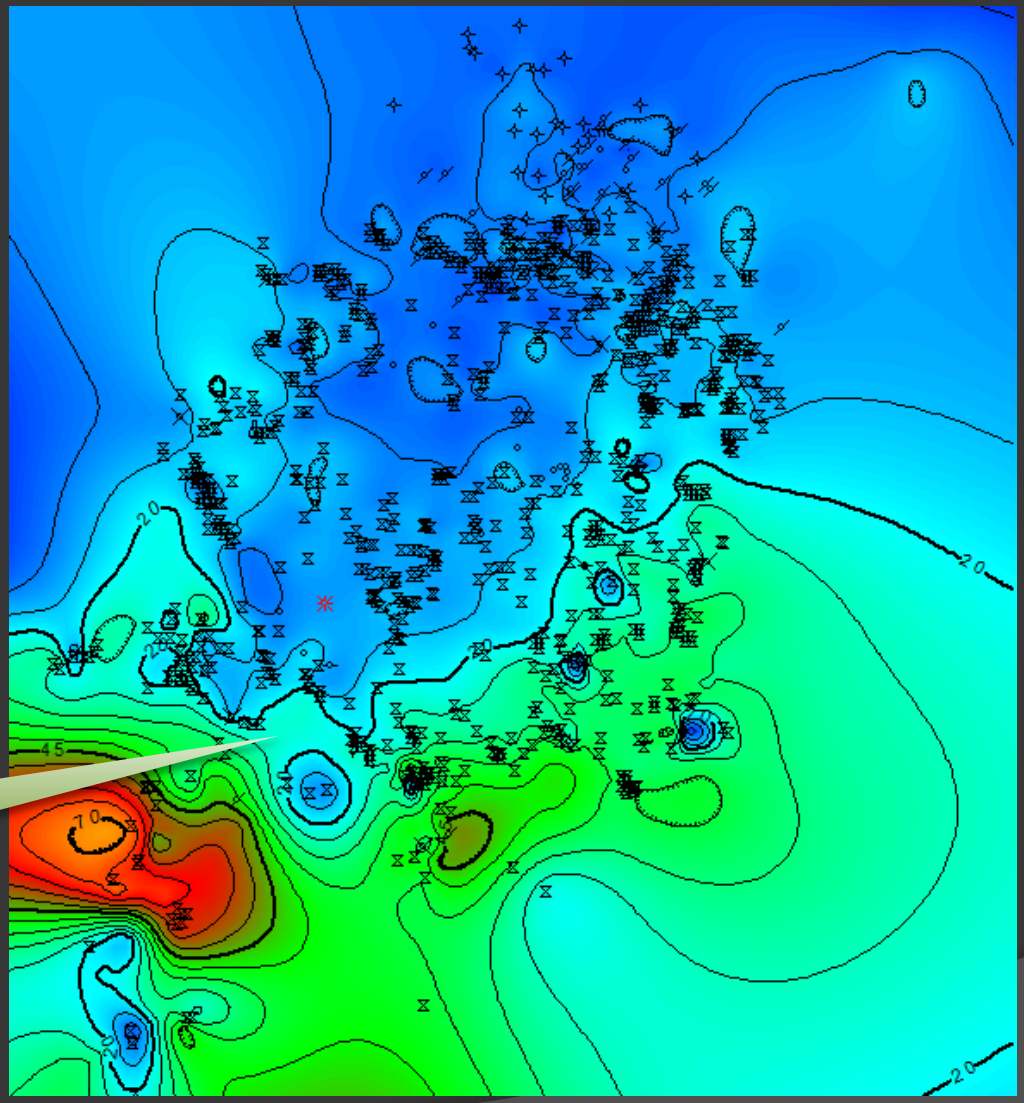


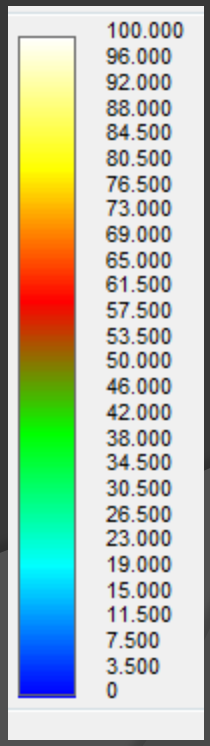
ILD (Deep Induction)



Isopach Thickness Map of CW600-CW605



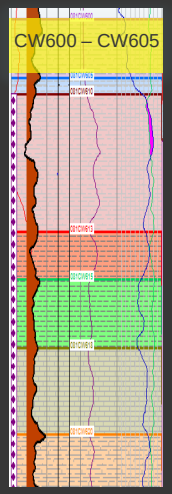




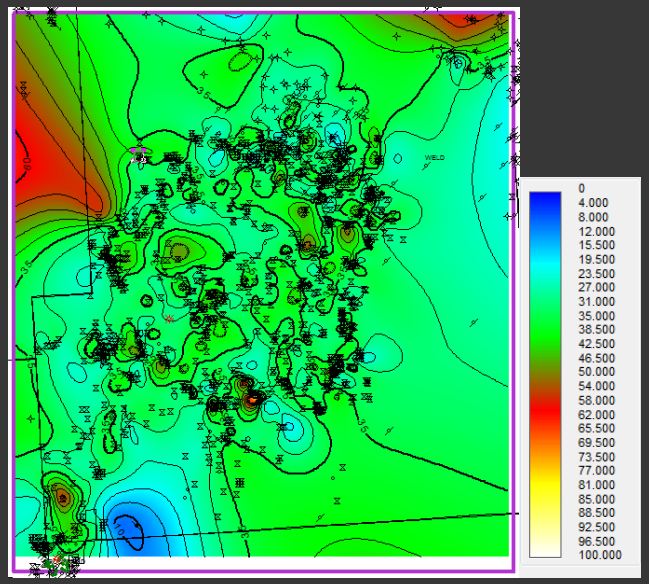
Movement of thickest parts indicate continuing regression

Log Attribute Analysis – CW600 – CW605

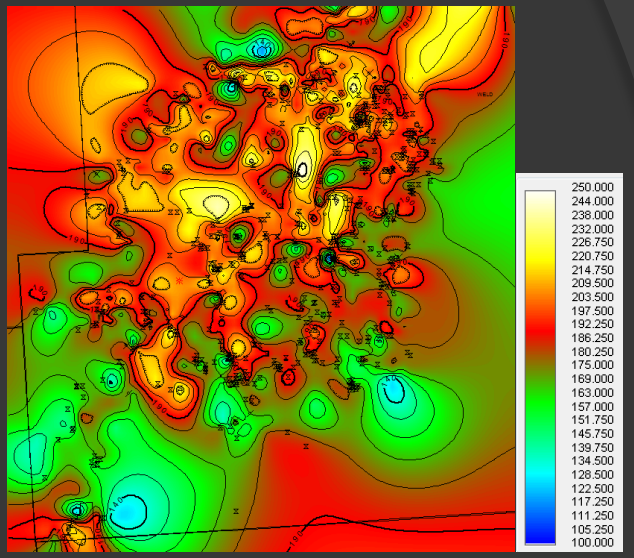
Log responses are highly variable for this unit



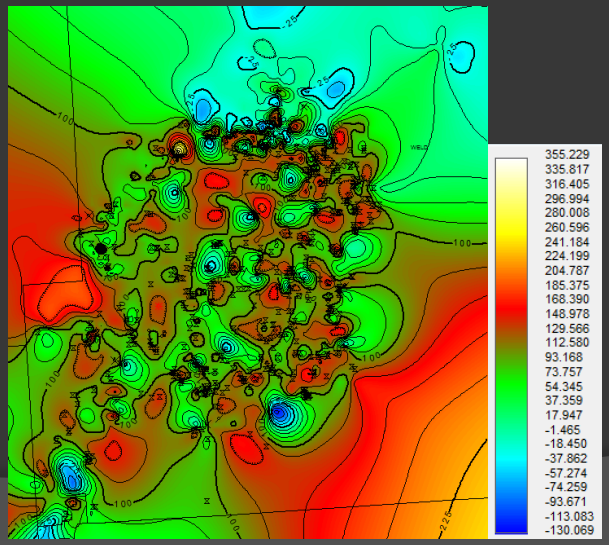
NPHI



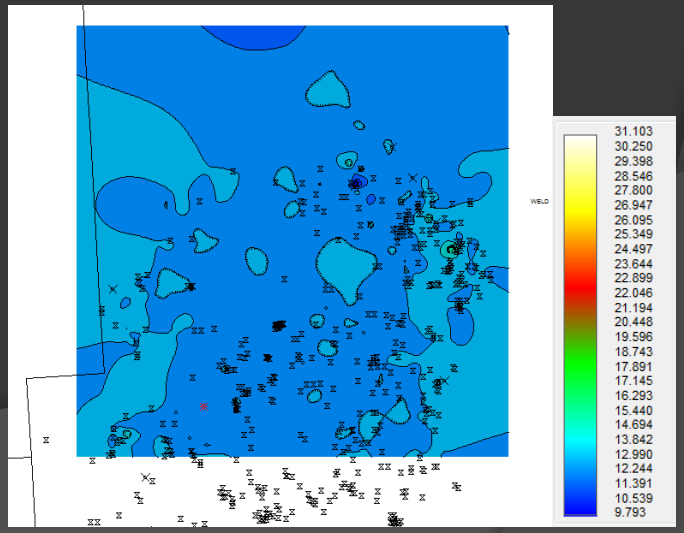
Gamma Ray



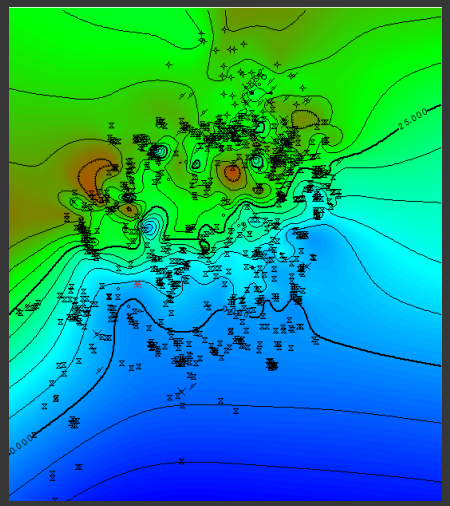
SP



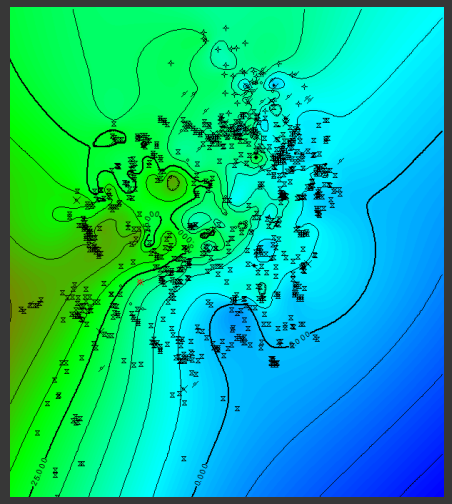
ILD (Deep Induction)



Isopach Map Series

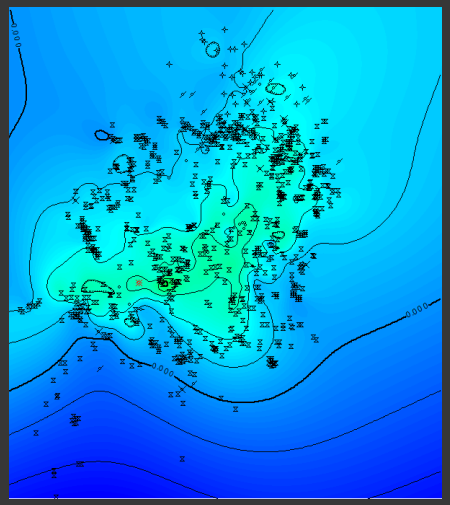


CW620-CW625

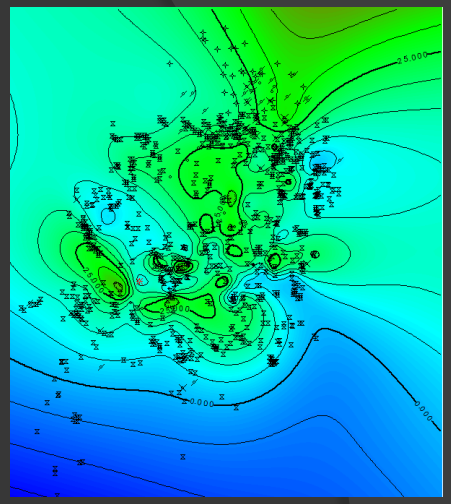


CW618-CW620

Deposition moving southward

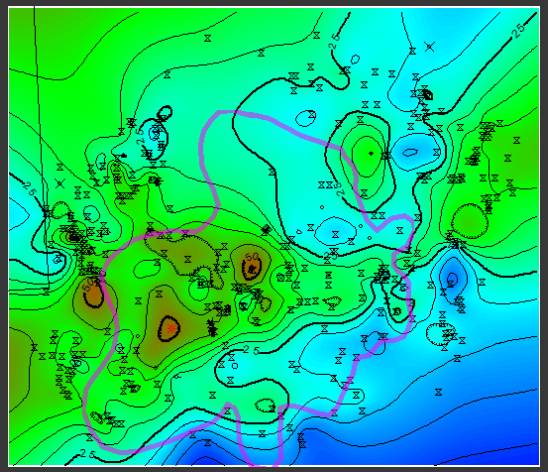


CW615-CW618

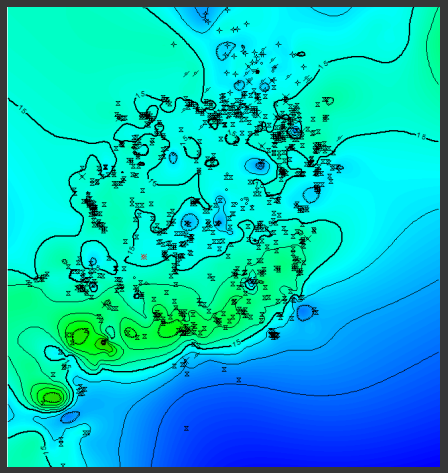


CW613-CW615

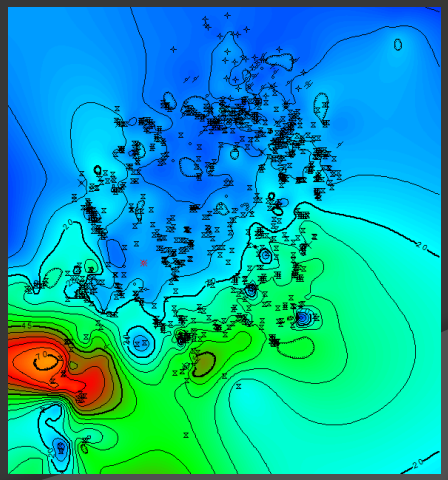
Deposition begins to build in center



CW610-CW613



CW605-CW610



CW600-CW605

Stacking in place, retrograde deposition

Thickest sections moving southward, regression

Conclusions

- Density crossover for the CW610-CW613 zone strongly correlates with known production.
- The lower average Gamma Ray readings also loosely correlate with the known production in the CW610-CW613 zone.
- The depositional patterns evidenced by the isopach maps of the parasequences composing the A-Bench of the Niobrara give clear evidence of the repeated transgressive-regressive events that were occurring during this period of the Denver-Julesburg Basin.
- At time study was concluded, an additional 450 wells with logs had been loaded into the project. Plans are underway to incorporate those into the results.