Buda and Georgetown of the Washita Group

DELOCATED

Summer 2019 Intern Project

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OUTLINE

Goals & Summary

Study Area

Stratigraphy & Depositional Environment

Cross Sections

Regional & Local Production

Structure & Isopach Maps

Conclusions I

Fracture Formation Hypotheses

Seismic Overview

Residual Trend Maps

Gravity Maps

Prospective Acreage

Conclusions II

References

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GOALS

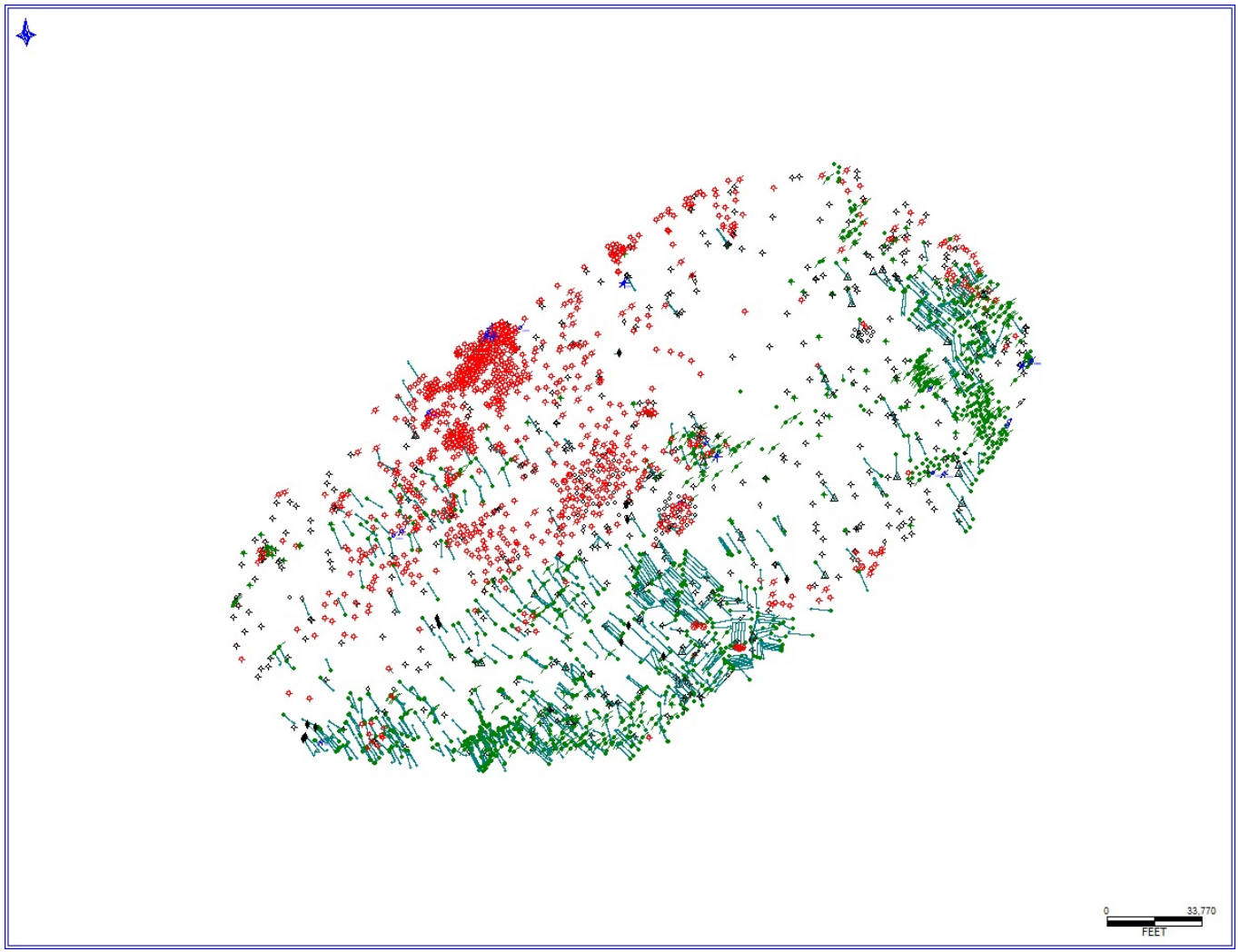
- Map and evaluate Washita stratigraphy in for future drilling potential.
- Integrate multiple data to identify/confirm the control on production (*likely natural fracturing).
- Identify prospective drilling targets.

**Julian Jr., 1982; Snyder & Craft, 1977; and others*

SUMMARY

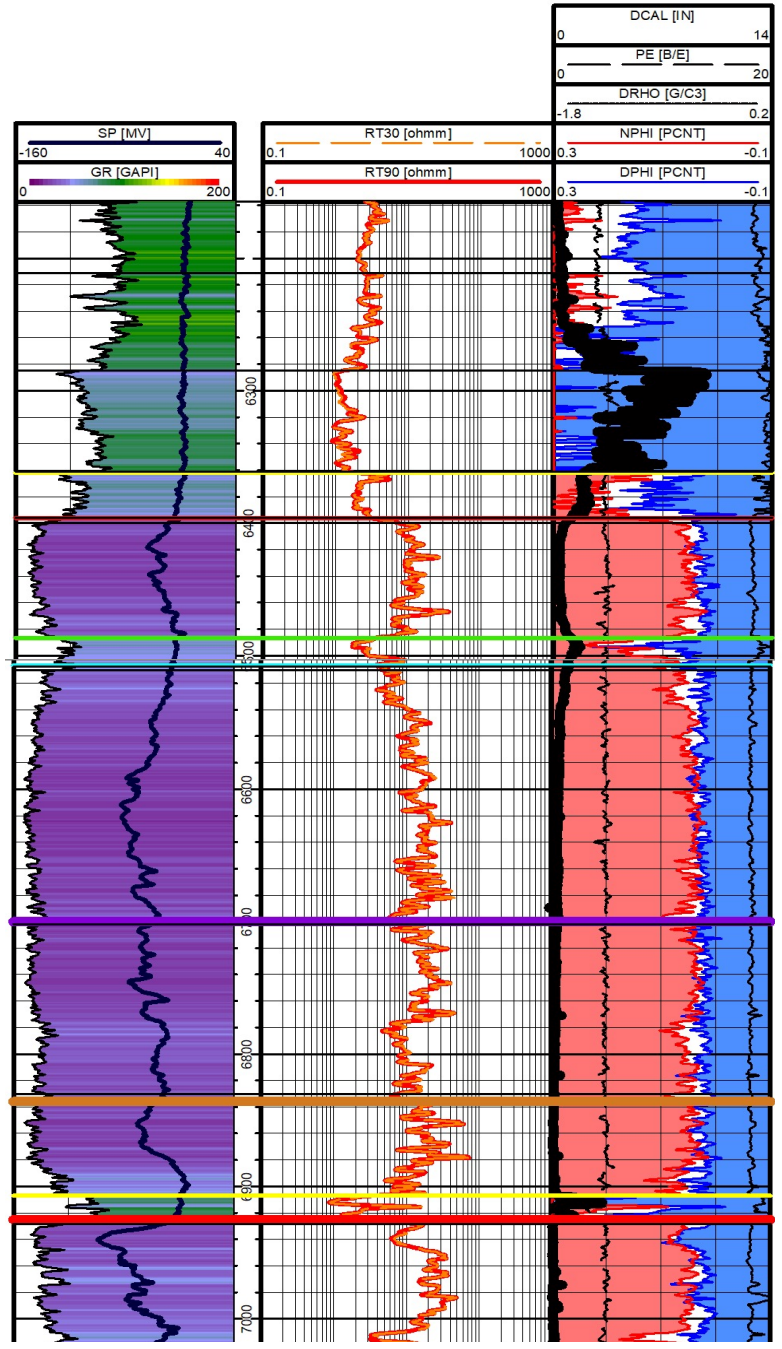
- Buda and Georgetown are low porosity (<3%) and low permeability (<1 md) carbonates.
- Poor correlation exists between net isopach maps (porosity maps) and areas of production.
- Seismic data exhibits dissimilarity (poor coherence) within the Buda / Georgetown in association with the XXXXX producing field. *Natural fractures?*
- Third order residual trend maps reveal correlation between positive residual structural features in the Buda / Georgetown and the XXXXXXX field. *Flexure causing natural fractures?*
- Isostatic gravity maps suggest the basement largely controls local structure.
- The Buda and Georgetown within current acreage appear to exhibit flat or negative local residual structure with limited evidence of fracturing. **Targeting these formations is not recommended**.

STUDY AREA DELOCATED



STRATIGRAPHY

SYSTEM	GROUP	STRATIGRAPHY
Upper Cretaceous		‘Eagle Ford’
Lower Cretaceous	*Washita Group*	False Buda
		Buda
		Del Rio
	Georgetown	Main Street
		Ft. Worth
		Duck Creek
		Kiamichi
		Goodland



Lithology & Misc.

BUDA

- Indurated, massive, fossiliferous micrite
- Low energy, shallow marine deposition
- Matrix porosity <3%, matrix permeability <0.1 md
- Natural fracturing at 1-25 fractures/ft.
- Fractures widths 0.1-0.4 mm.

(*McClelland, 2003; Snyder & Craft, 1977; Brown, 1971*)

GEORGETOWN

- Irregularly-interbedded, fossiliferous micrite and marl
- Low energy, shallow marine deposition.
- Low porosity and permeability similar to Buda.
- Production also natural fracture controlled.

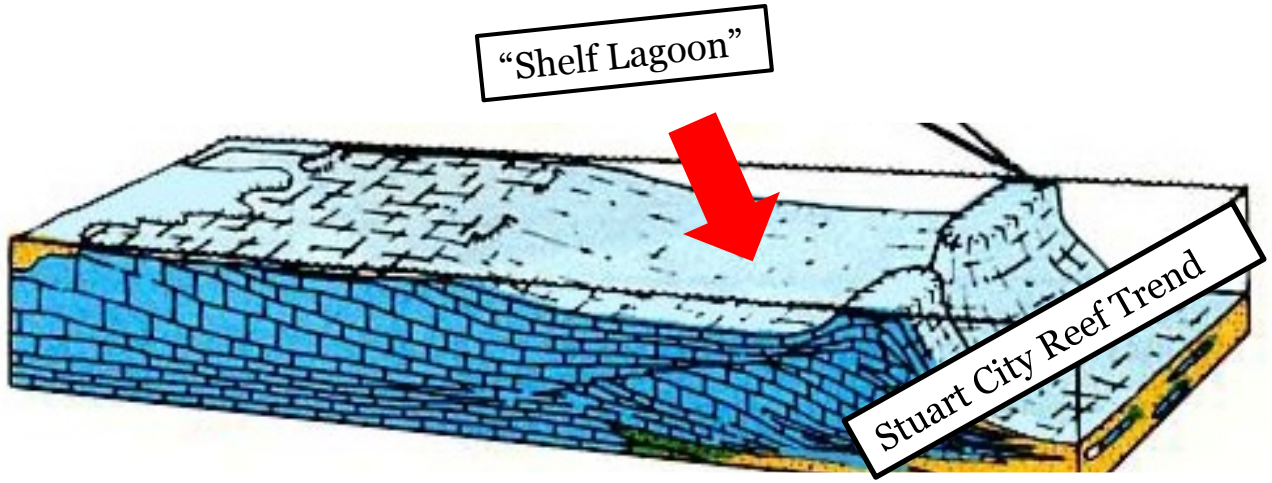
(*McClelland, 2003; Julian Jr., 1982, Mostellar, 1970*)

*Woodbine & Sub-Clarksville not broken from Eagle Ford in this study.

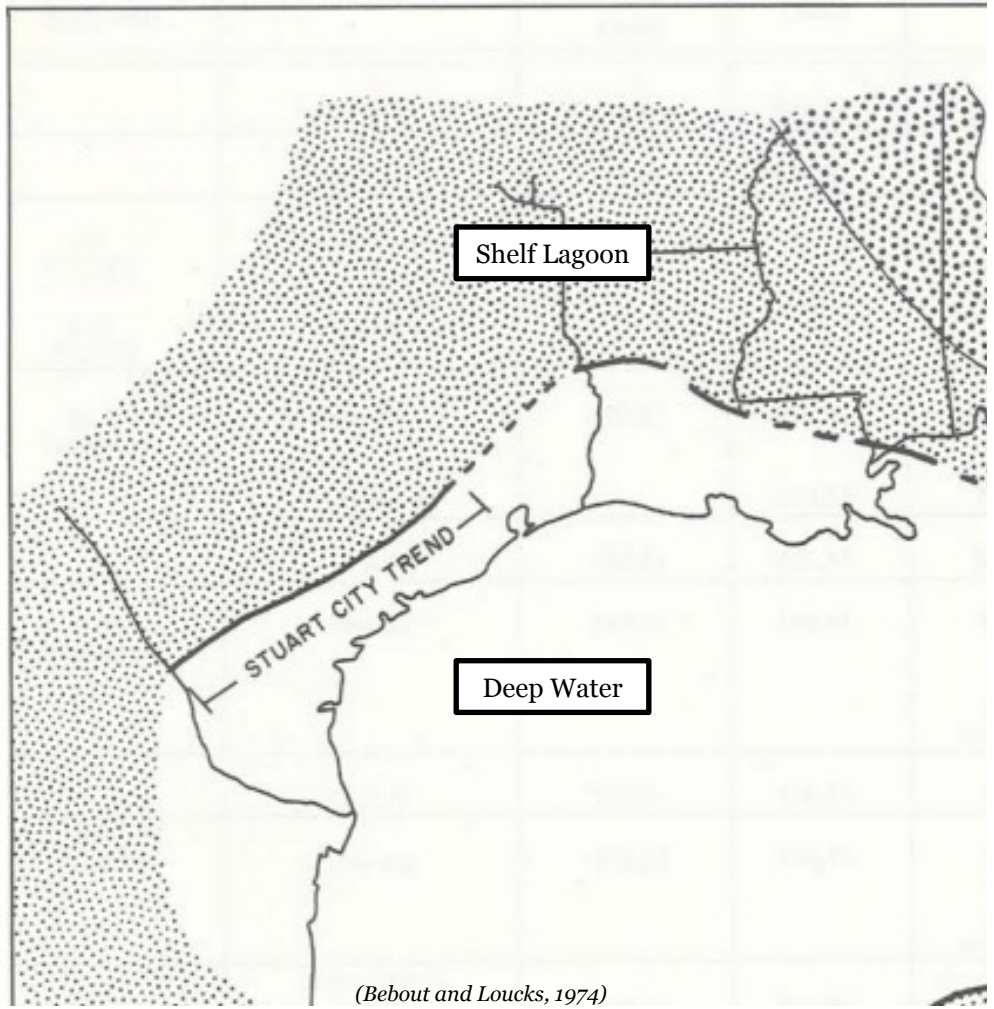
Depositional Environment

Lower Cretaceous – Washita Group

- Epi-continental sea forms broad rimmed carbonate shelf environment (*Bebout & Loucks, 1974; Brown, 1971*)
- Continuous pelagic rain of blue-green algae results in widespread low porosity and permeability lime mud. *(Bebout & Loucks, 1974; Brown, 1971)*
- Stratigraphy gently dips SE to meet with Stuart City Reef Trend and thickens regionally to the NE (*Mosteller, 1970*)



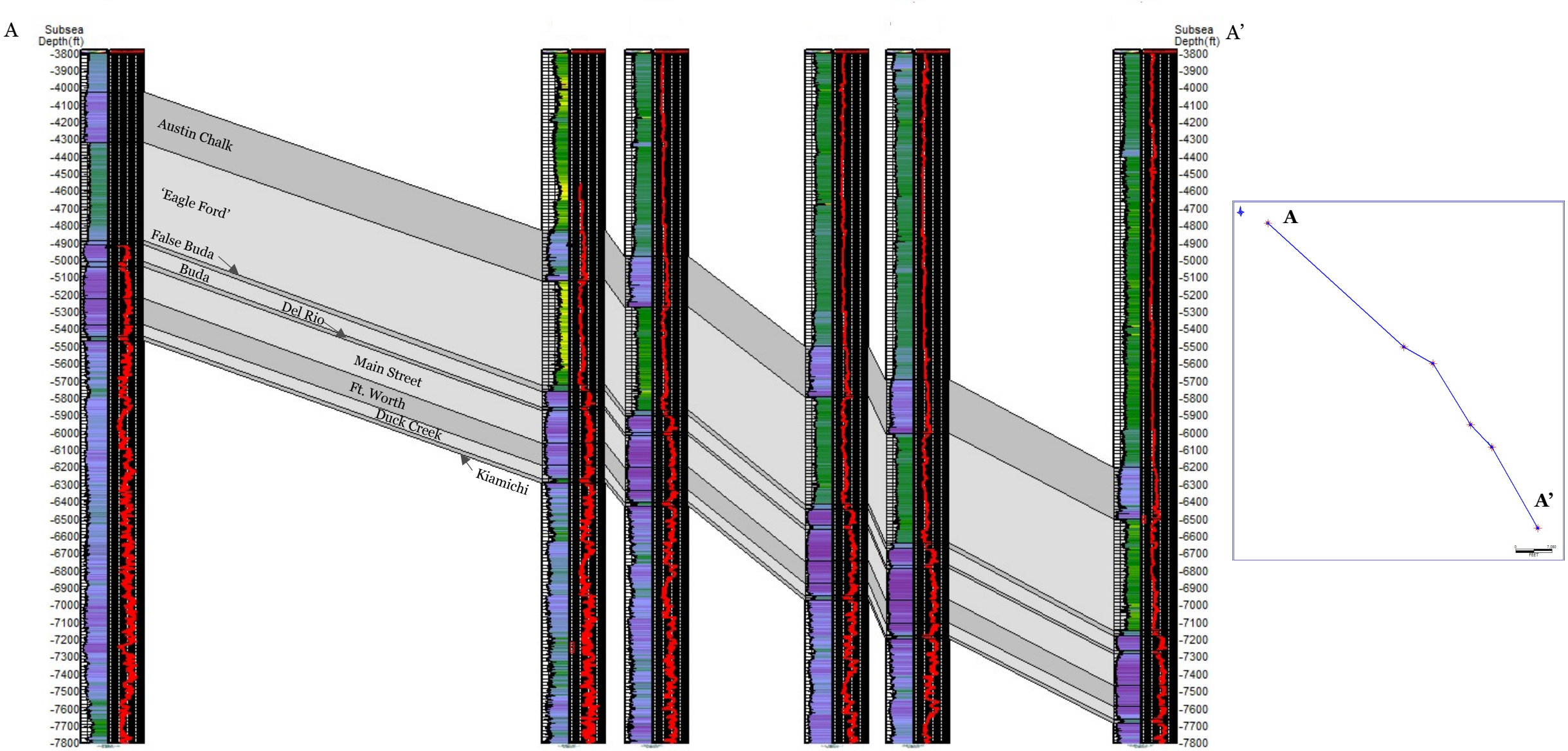
http://www.sepmstrata.org/page.aspx?pageid=93



(Bebout and Loucks, 1974)

STRUCTURAL CROSS SECTION

Approximate Dip

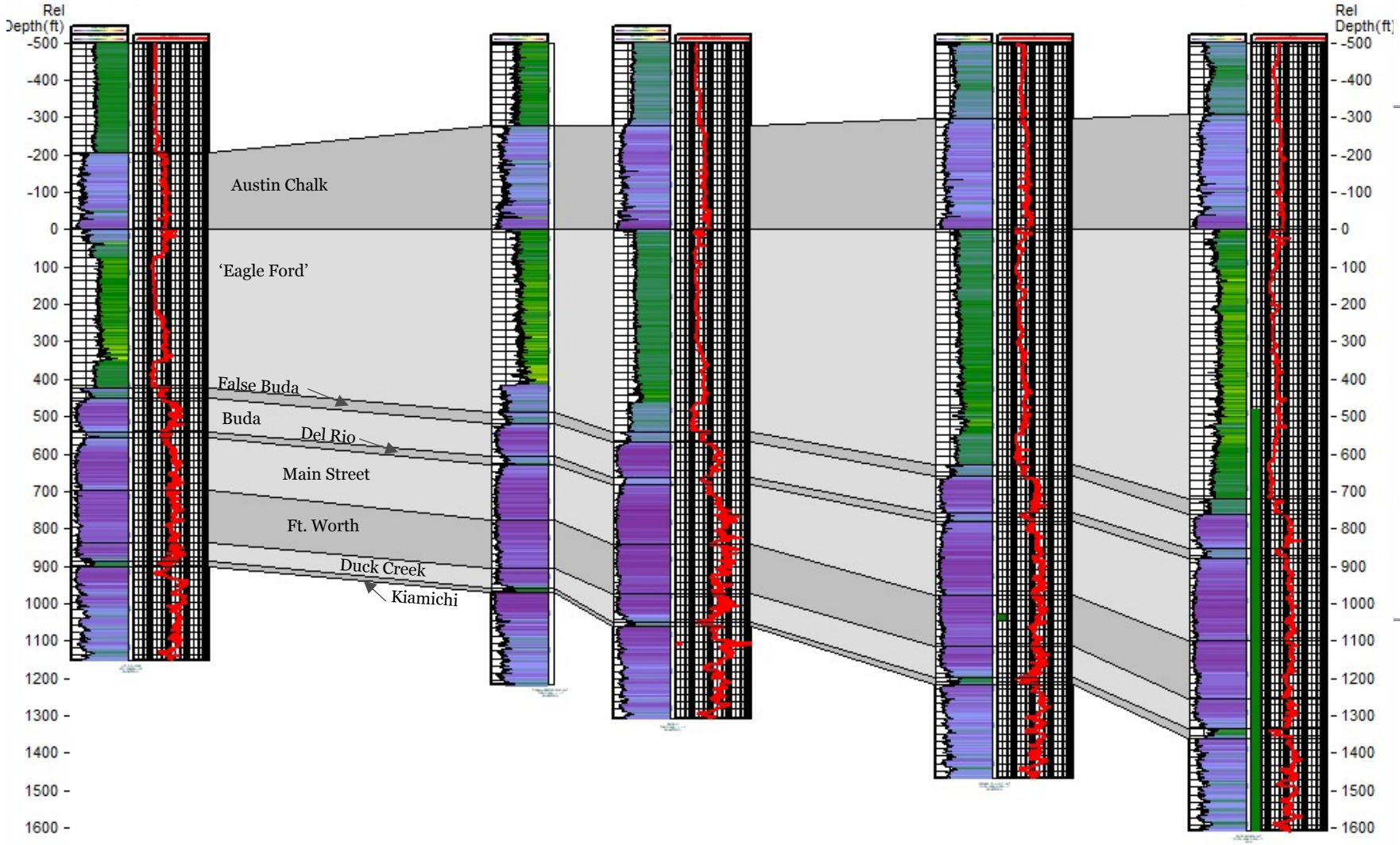


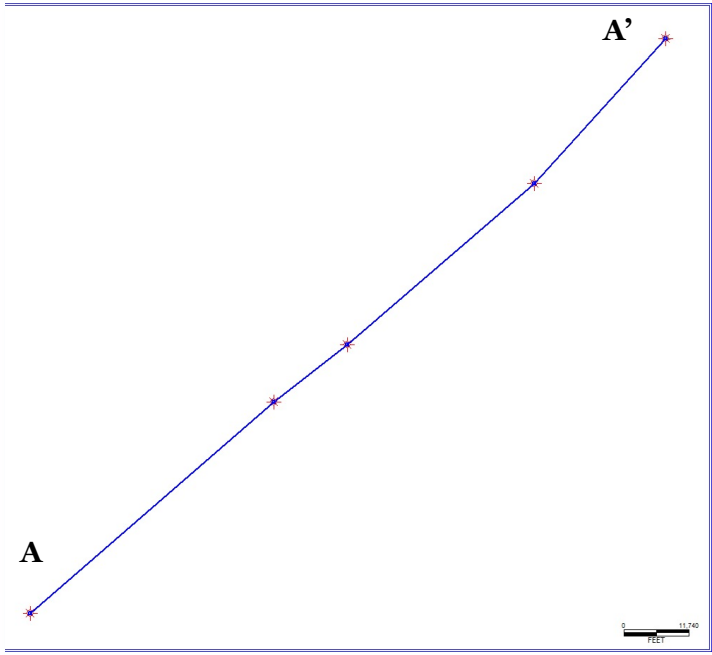
STRATIGRAPHIC CROSS SECTION

Approximate Strike, Flattened on Base of Austin Chalk

A

A’

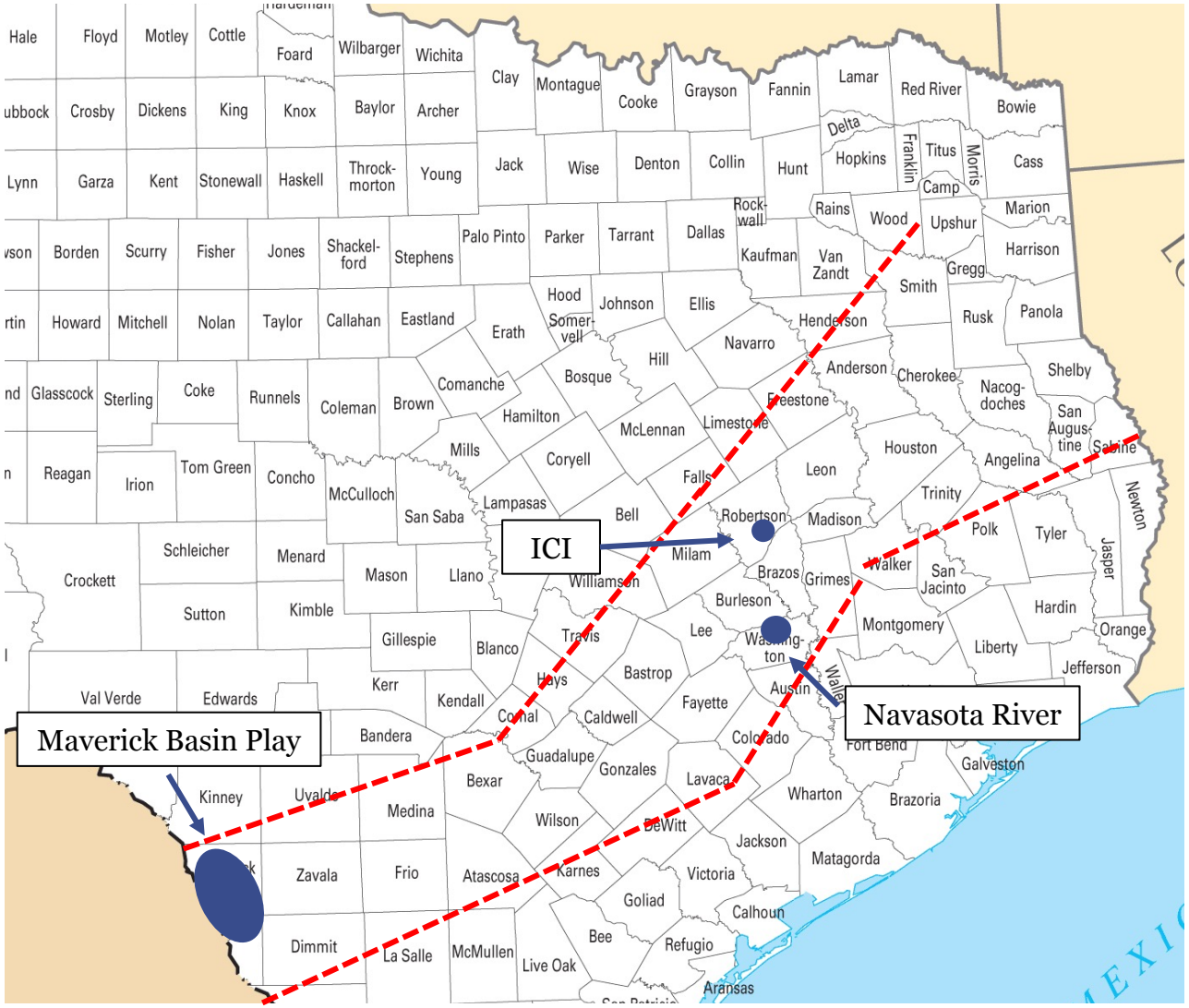




REGIONAL CONTEXT

Buda Production Fairway

Georgetown Production "Hot-Spots"



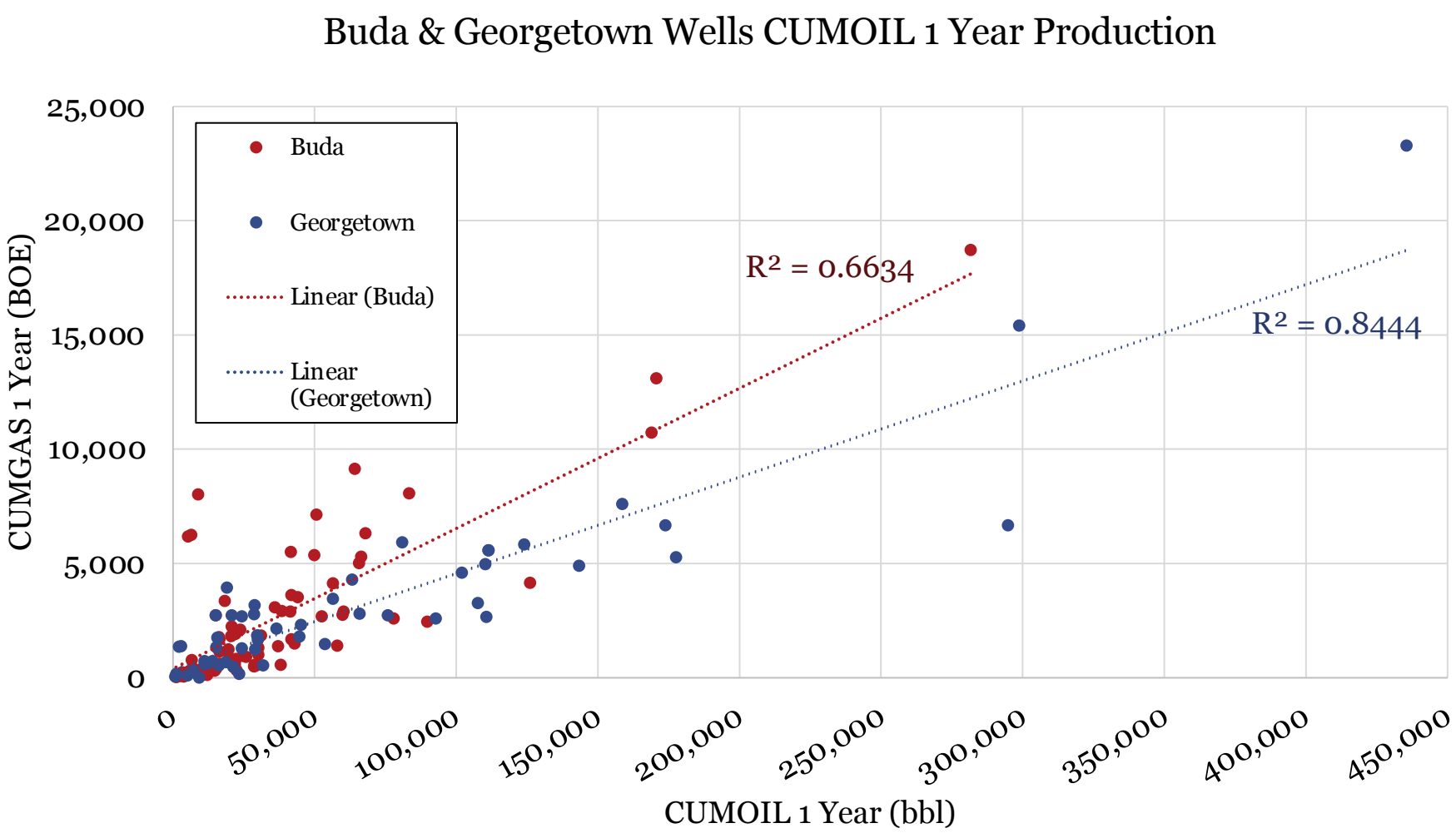
Adapted from:
(Parker, 2000)
https://www.energyfrontierspartners.com/budageorgetown.htm

Austin Chalk Trend

https://seekingalpha.com/article/4246902-austin-chalk-revived-emerging-unconventional-play

LOCAL PRODUCTION

DIRECTIONAL WELLS ONLY



Well Count	
Buda	69
Georgetown	53
Combined	**122**

Total Production (1 Year)	
Buda Oil	2,713,291 bbl
Buda Gas	193,939 BOE
Buda 'GOR'	0.071 BOE:bbl
Georgetown Oil	3,572,686 bbl
Georgetown Gas	169,012 BOE
Georgetown 'GOR'	0.047 BOE:bbl
Combined Oil	**6,285,977 bbl**
Combined Gas	362,951 BOE
'GOR'	0.058 BOE:bbl

*Two high gas outliers removed, viewable in Appendix E
*Only 7 vertical wells with confirmed production: excluded from statistics.

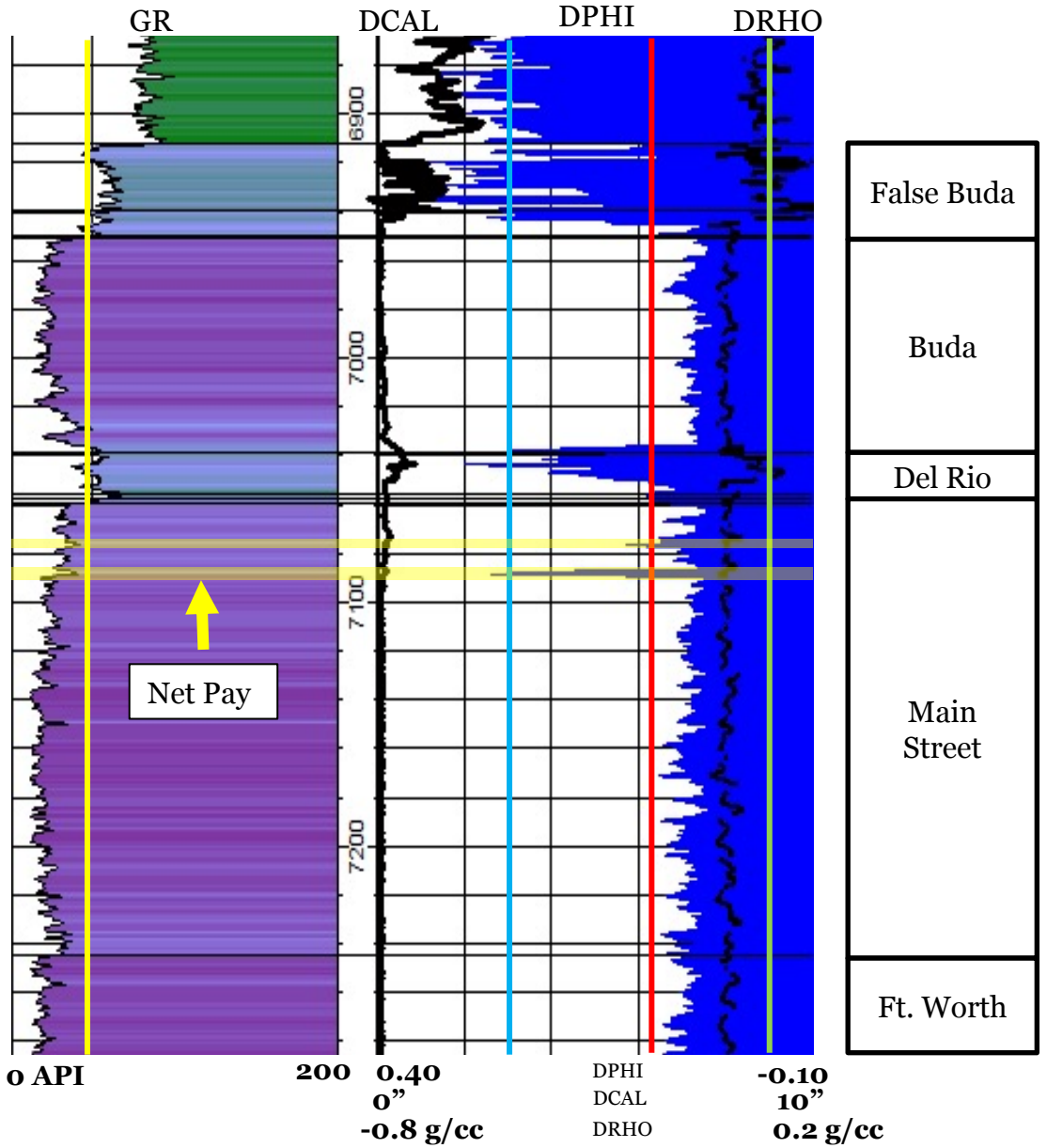
*Laterals generally ~1 mile, late 1990's

NET ISOPACH METHODOLOGY

Log Parameters:

Gamma Ray	≤45 API (personal discretion)	Yellow Cutoff
Density Porosity	≥8% (Snyder & Craft, 1977)	Red Cutoff
Density Correction	Between -0.1 & +0.1 (Scott Lapierre, Shale Specialist LLC, Personal Comm., 2019)	Green Cutoff
Washout	≤2.5" or ≤3.5" (personal discretion)	Blue Cutoff

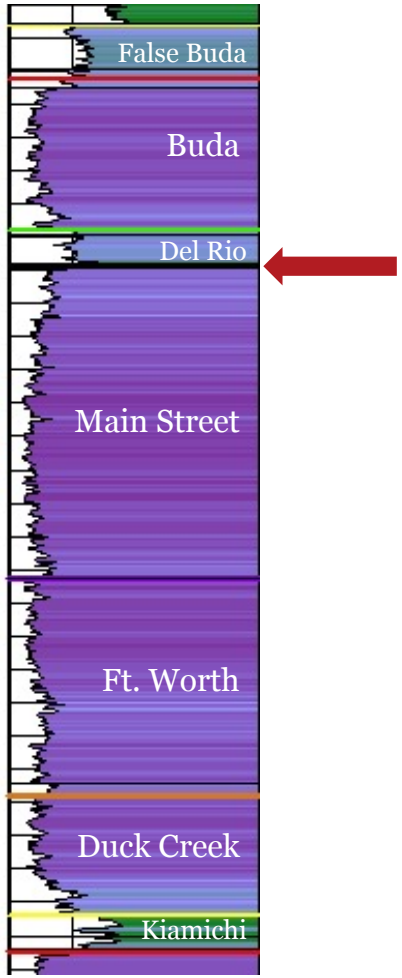
- All vertical and horizontal wells within study area with viable logs evaluated for pay (~274 wells)
- Both Raster and LAS pay incorporated into net isopach maps.
- Only 6 wells with production also had logs suitable for picking pay. 5/6 are poor wells with <5 ft of pay. Remaining well produced gas and is viewable in Appendix A.

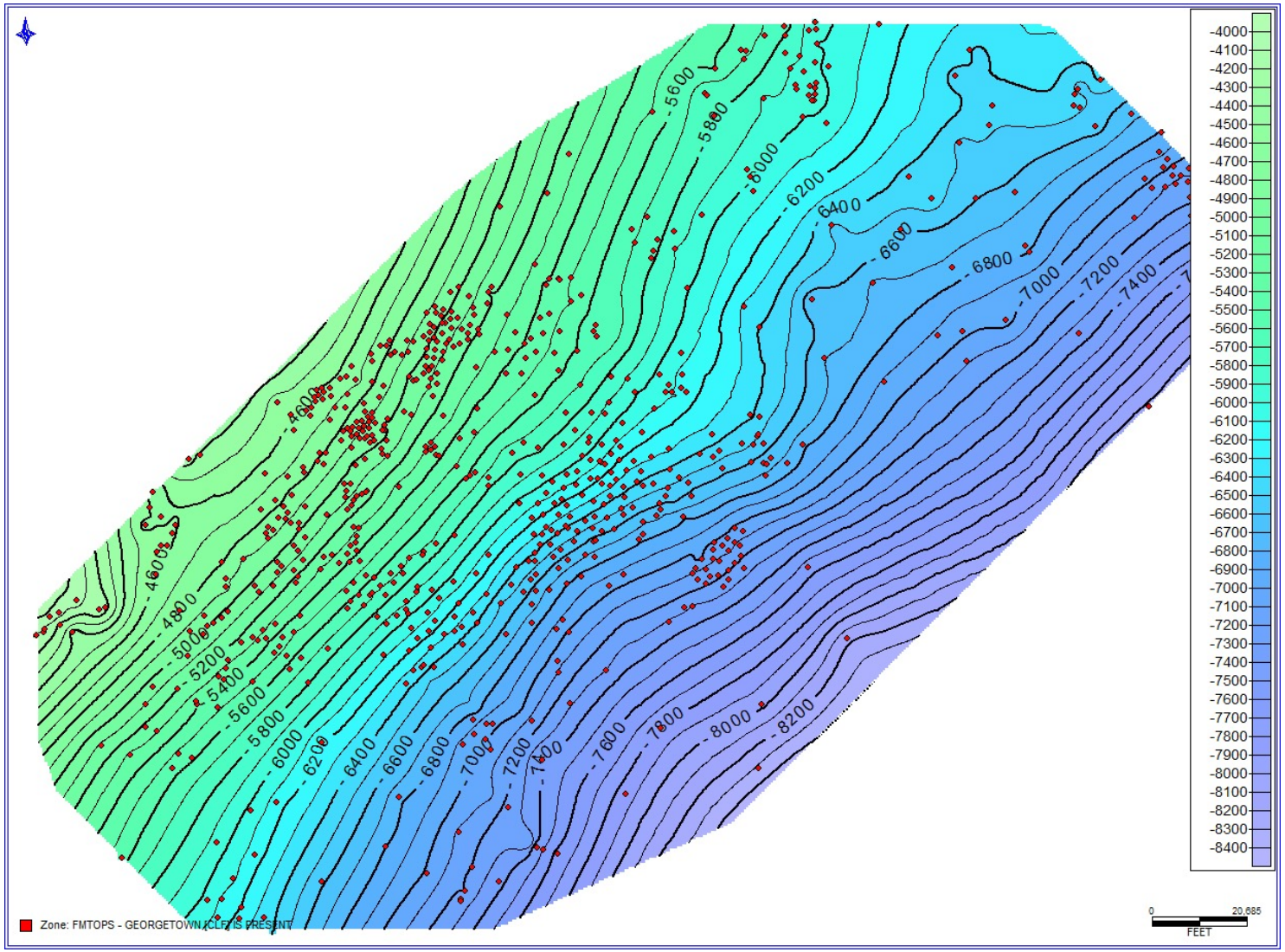


See **APPENDIX A** for additional methodology

STRUCTURE

Top of Main Street

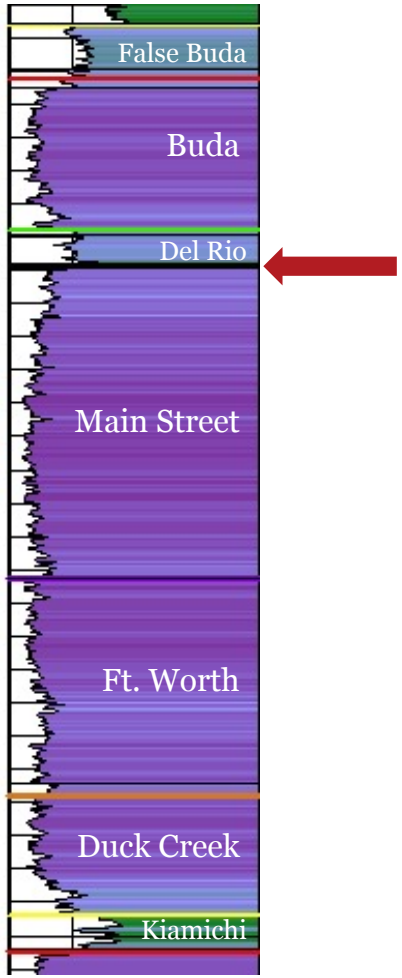


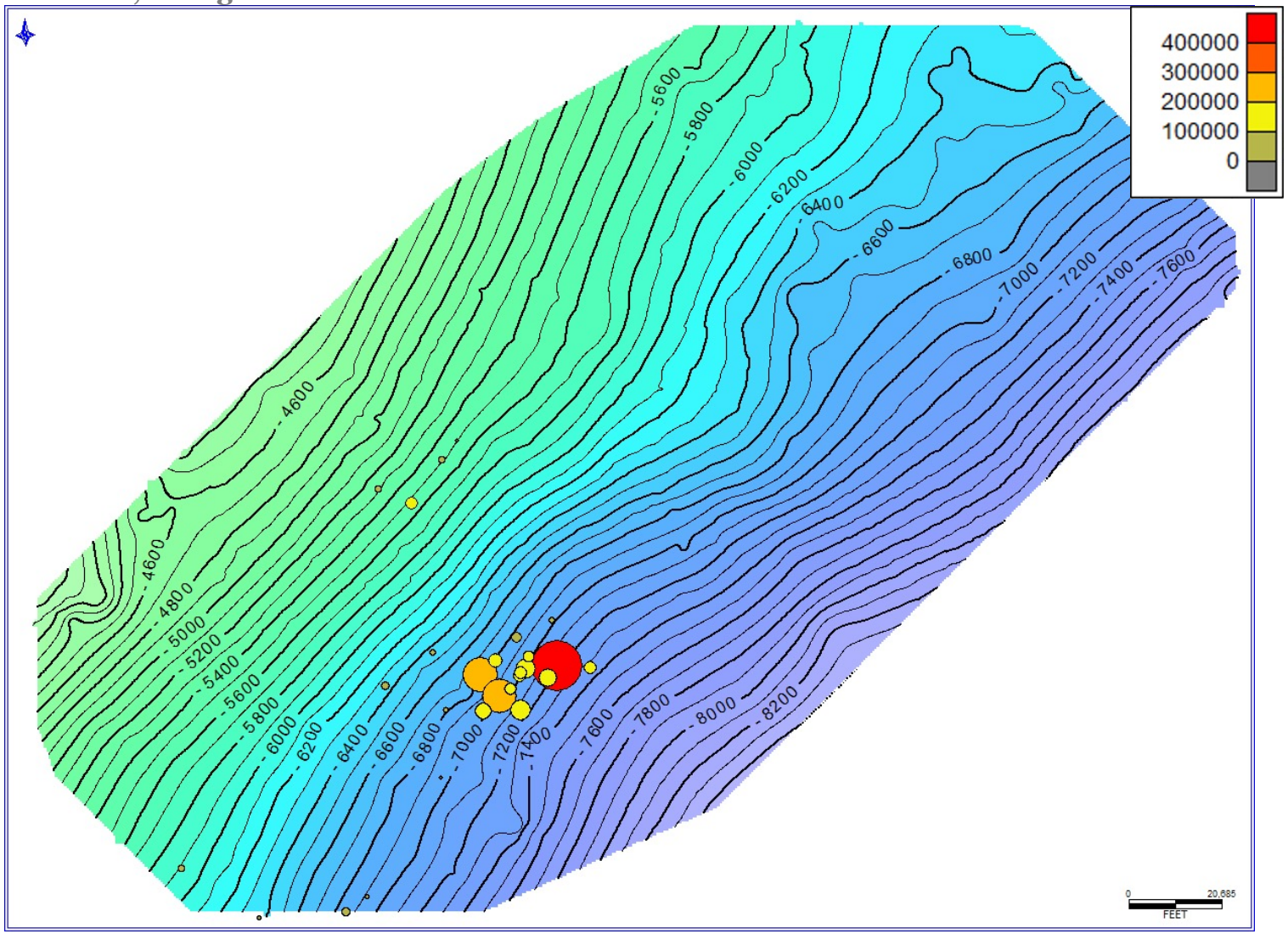


See **APPENDIX B** for additional maps

STRUCTURE + PRODUCTION

Top of Main Street; CUMOIL 1 Year, Georgetown Directional Wells





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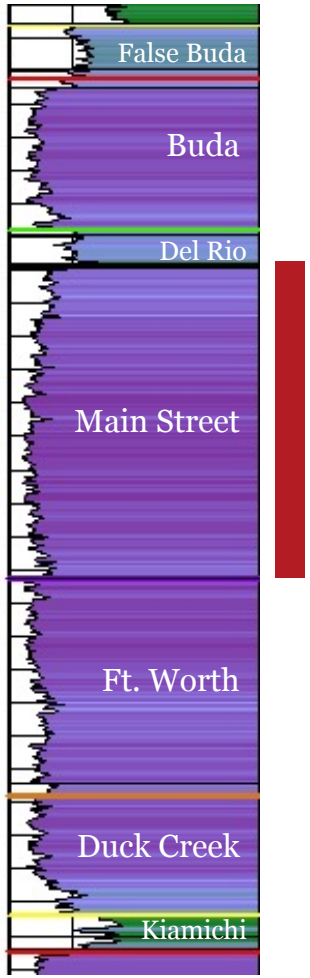
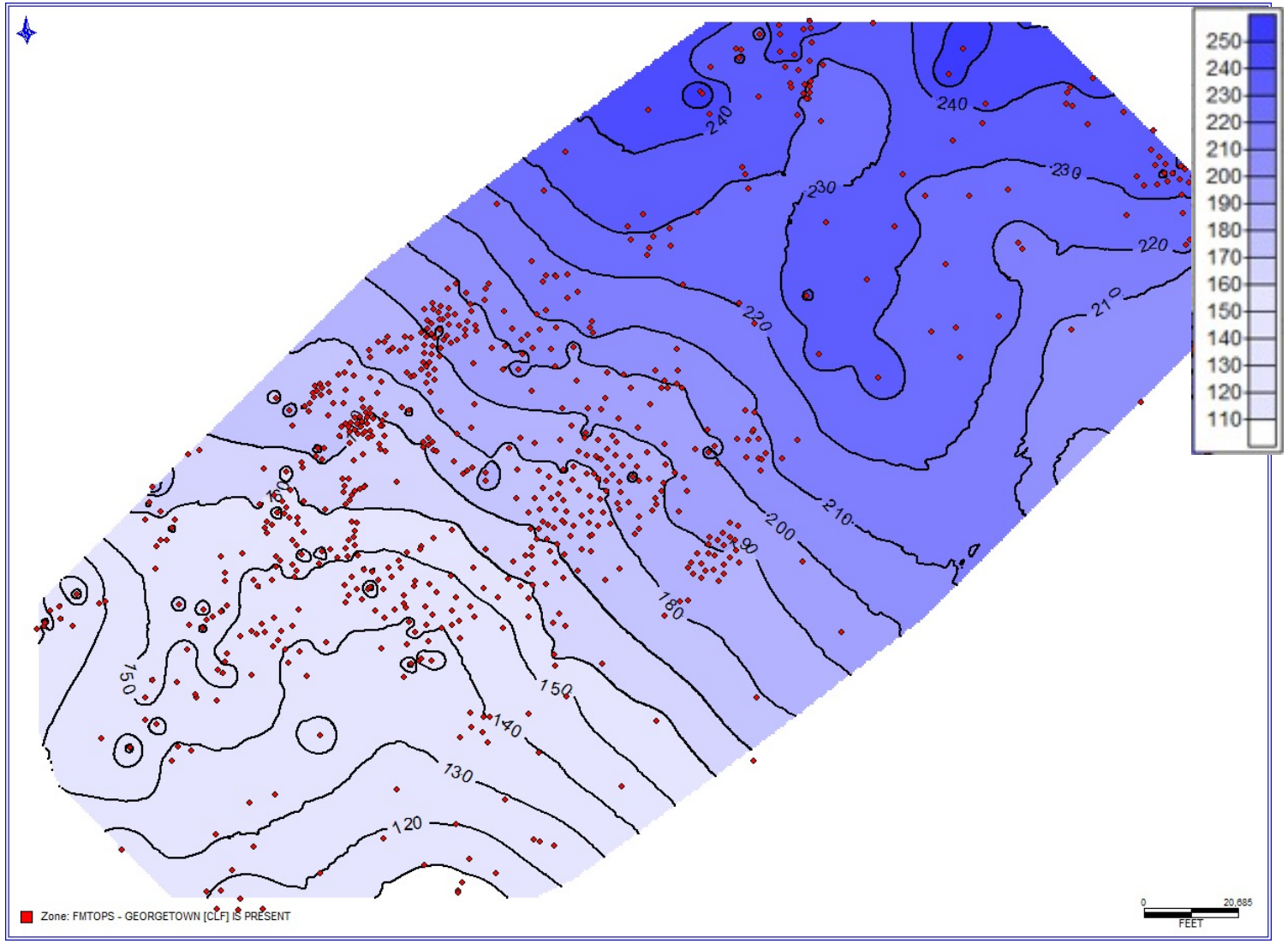
GROSS ISOPACH

Main Street





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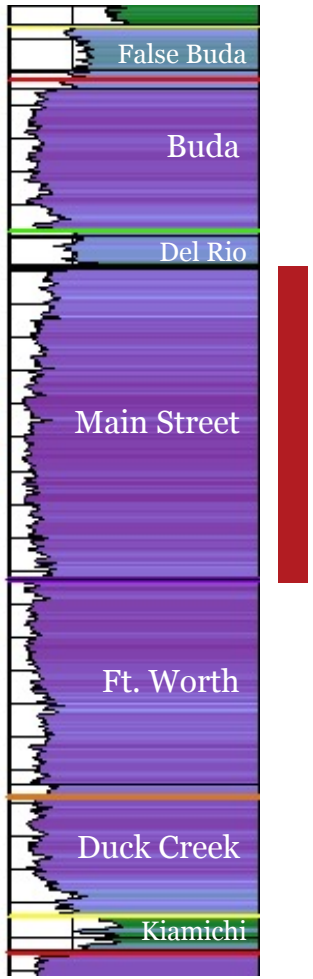
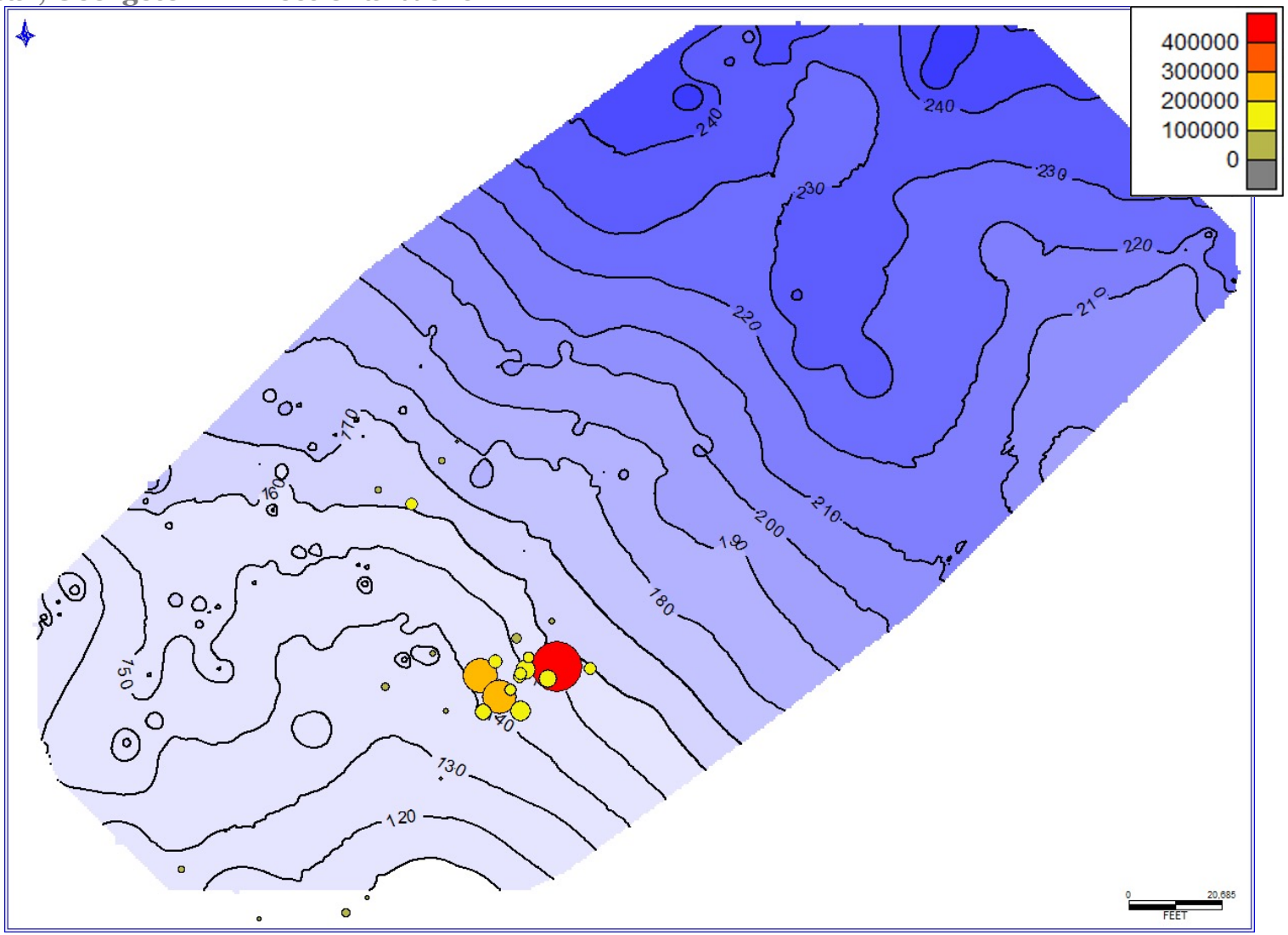
GROSS ISOPACH + PRODUCTION

Main Street; CUMOIL 1 Year; Georgetown Directional Wells





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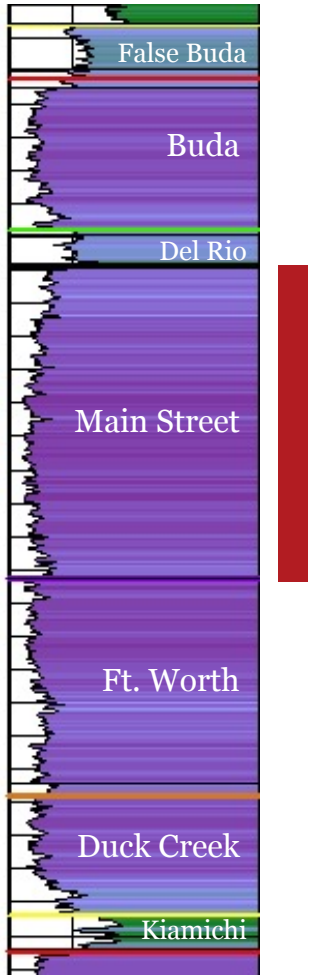
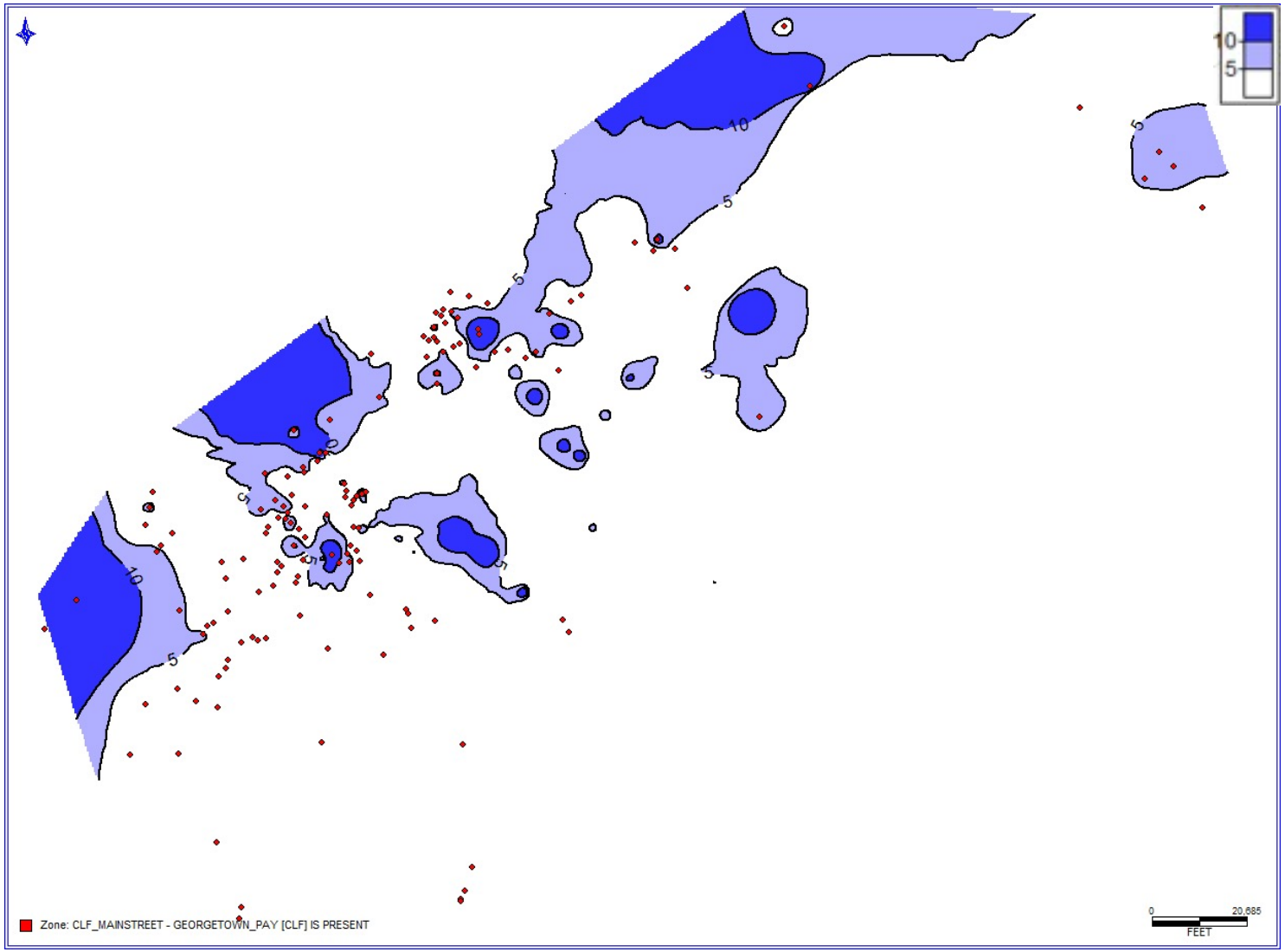
NET ISOPACH

Main Street





Gamma Ray	≤45 API
Density Porosity	≥8%
Density Correction	Between -0.1 & +0.1
Washout	≤2.5” or ≤3.5”

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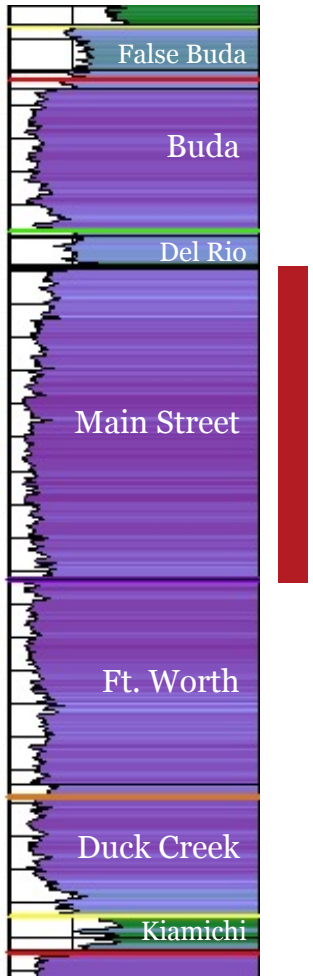
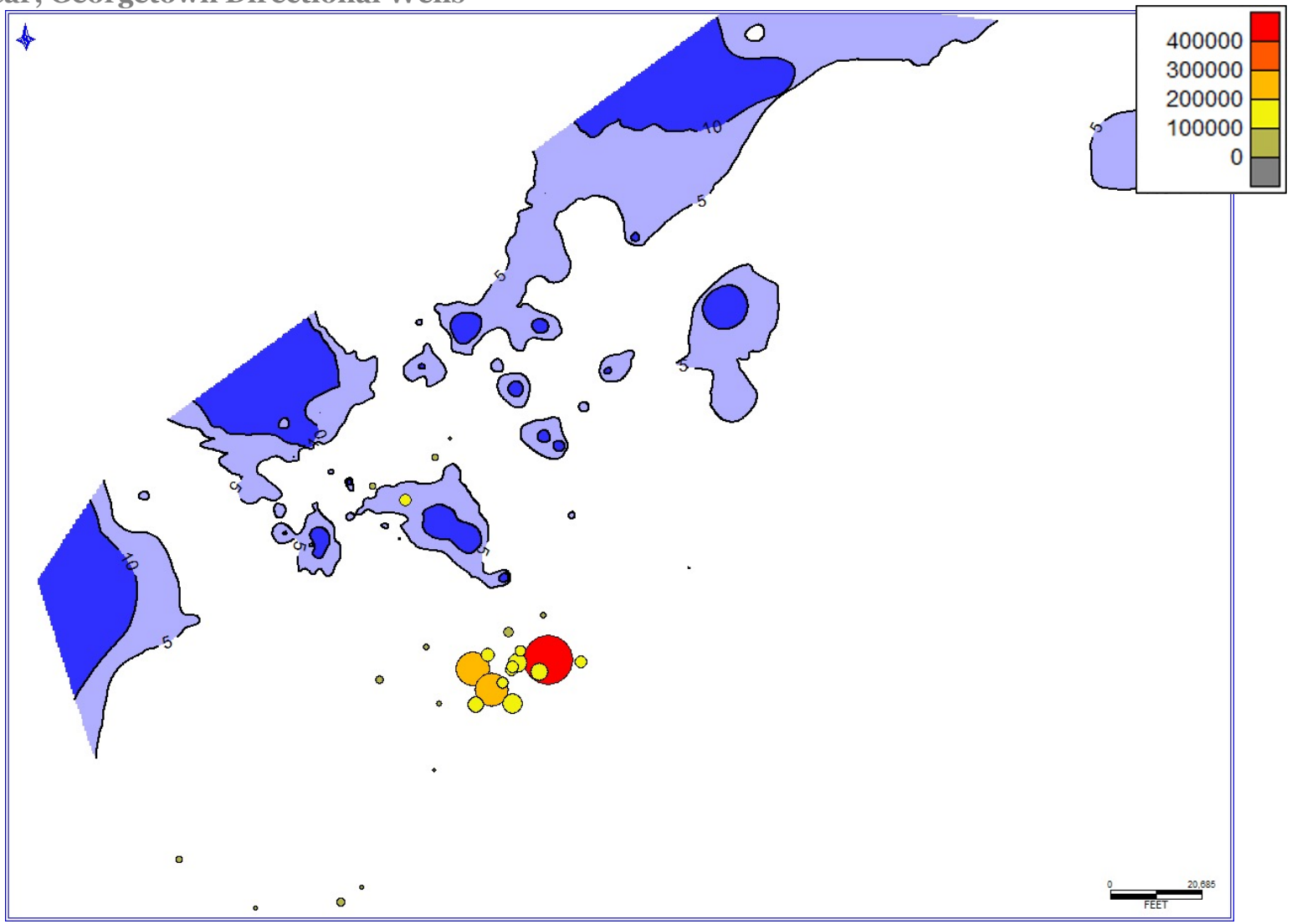
NET ISOPACH + PRODUCTION

Main Street; CUMOIL 1 Year; Georgetown Directional Wells





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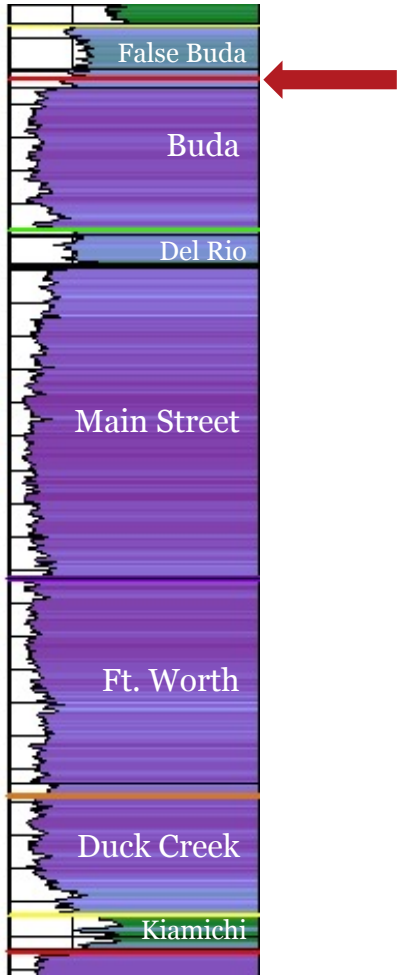
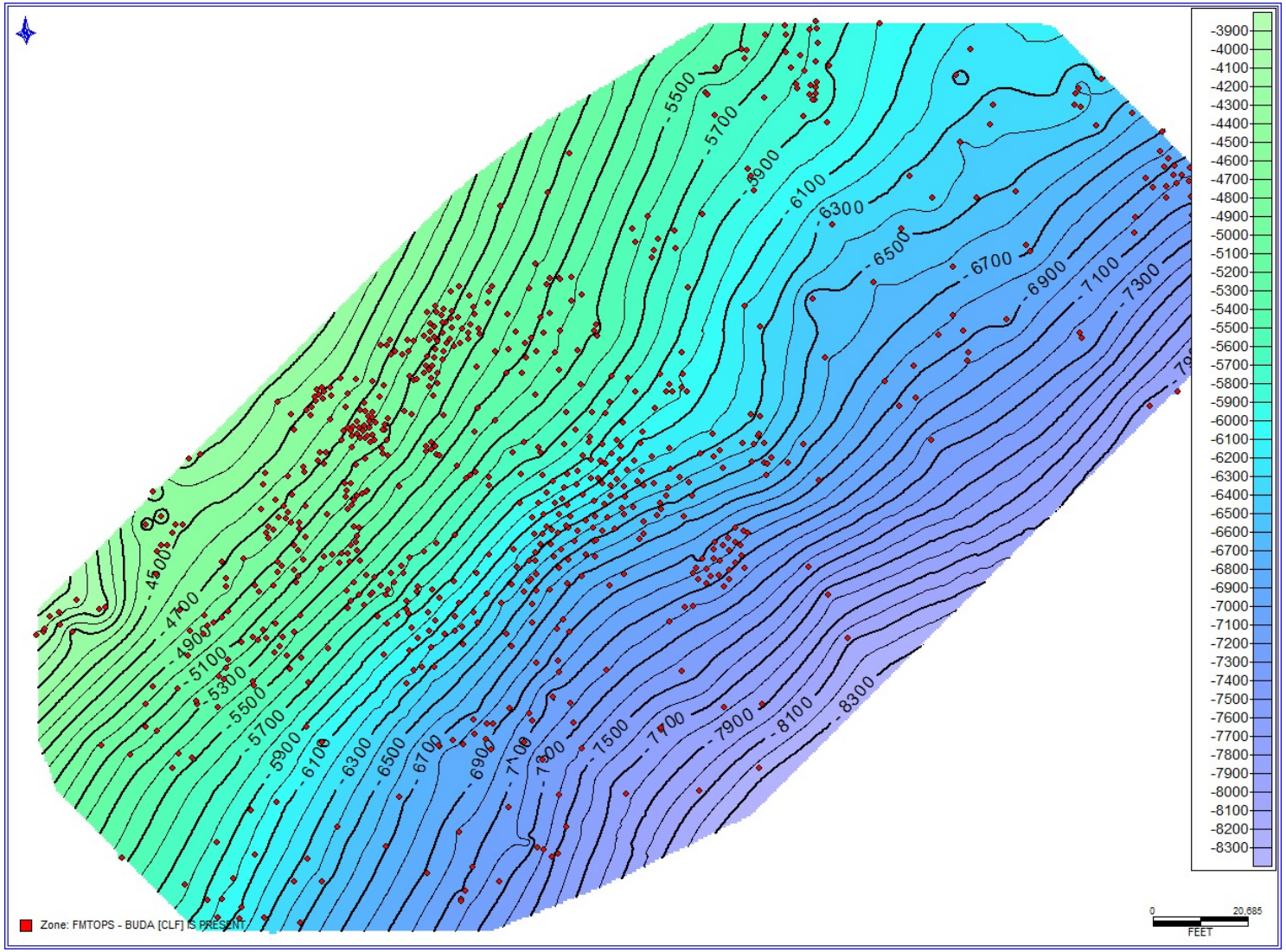
STRUCTURE

Top of Buda





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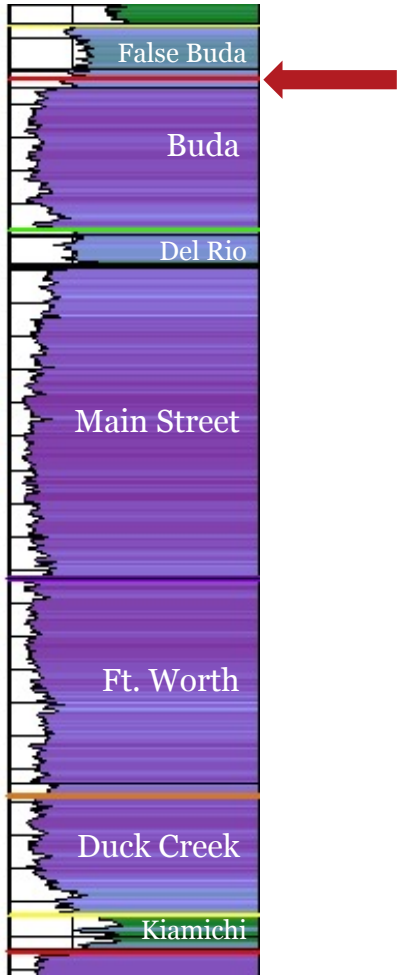
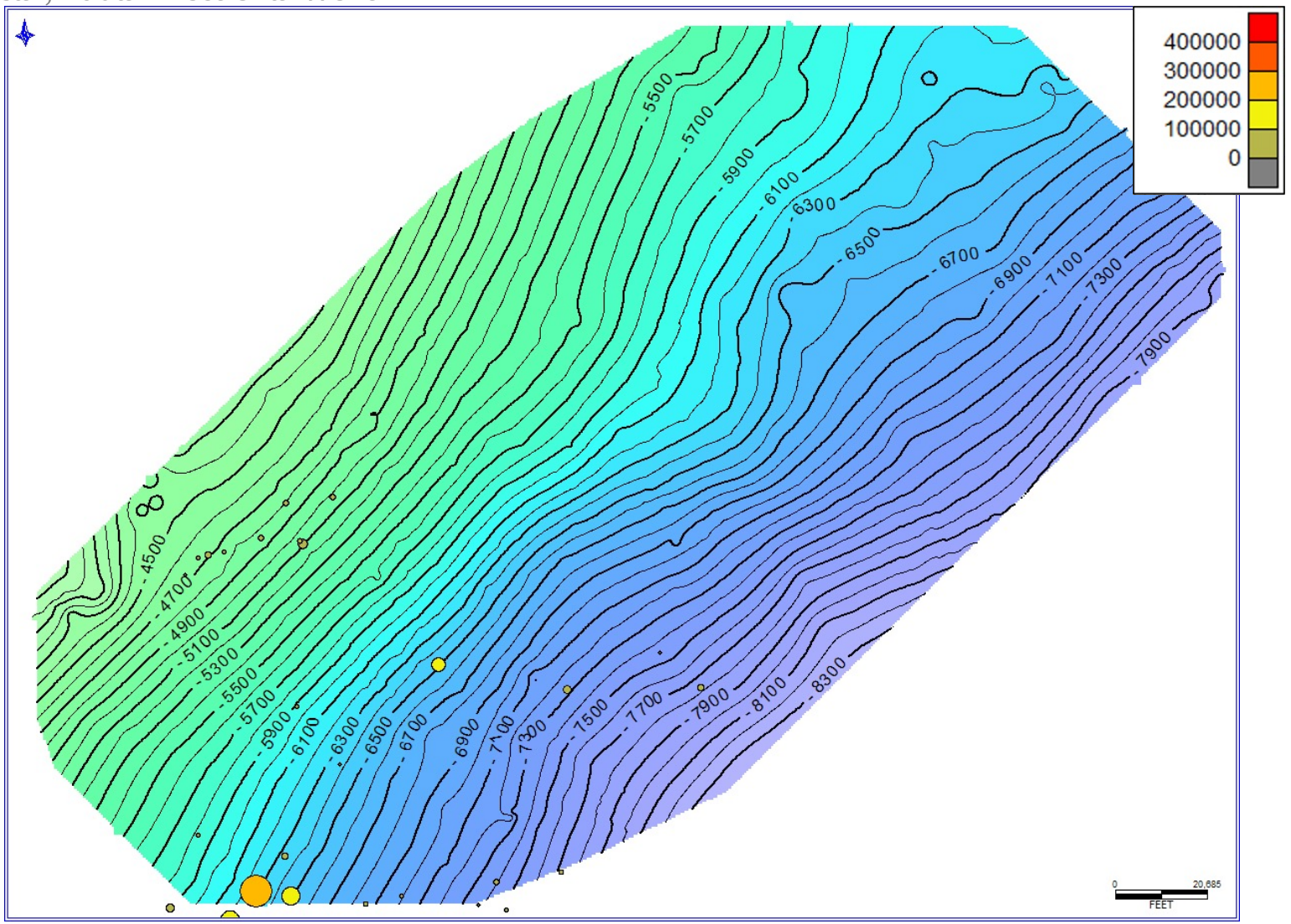
STRUCTURE

Top of Buda; CUMOIL 1 Year; Buda Directional Wells





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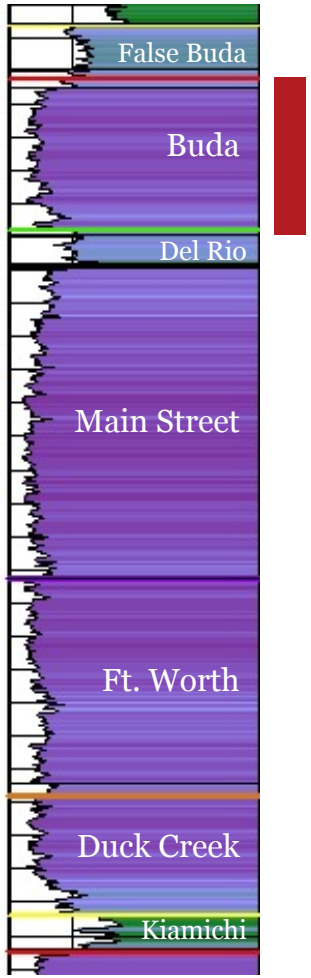
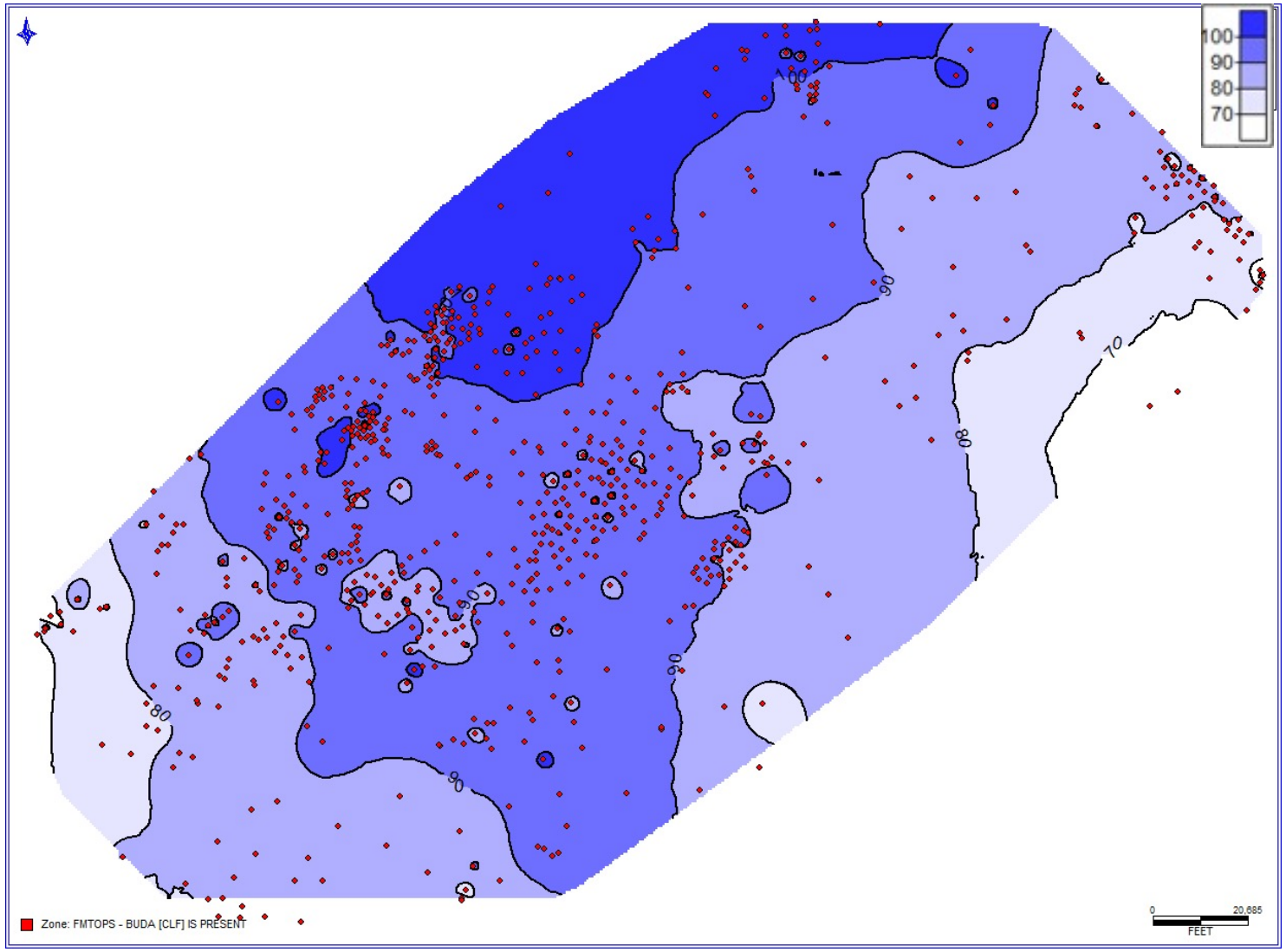
GROSS ISOPACH

Buda





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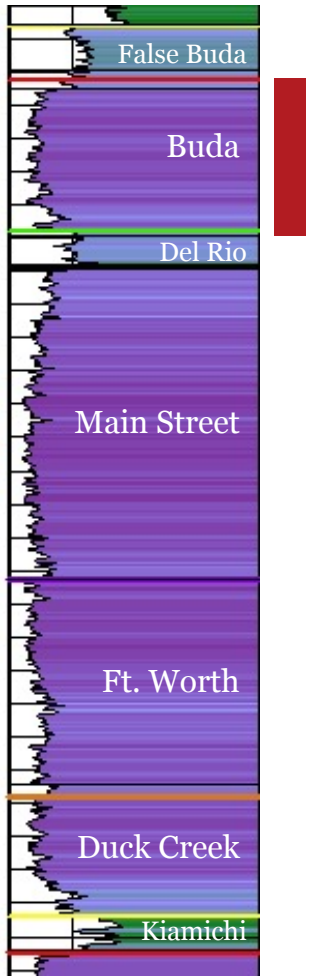
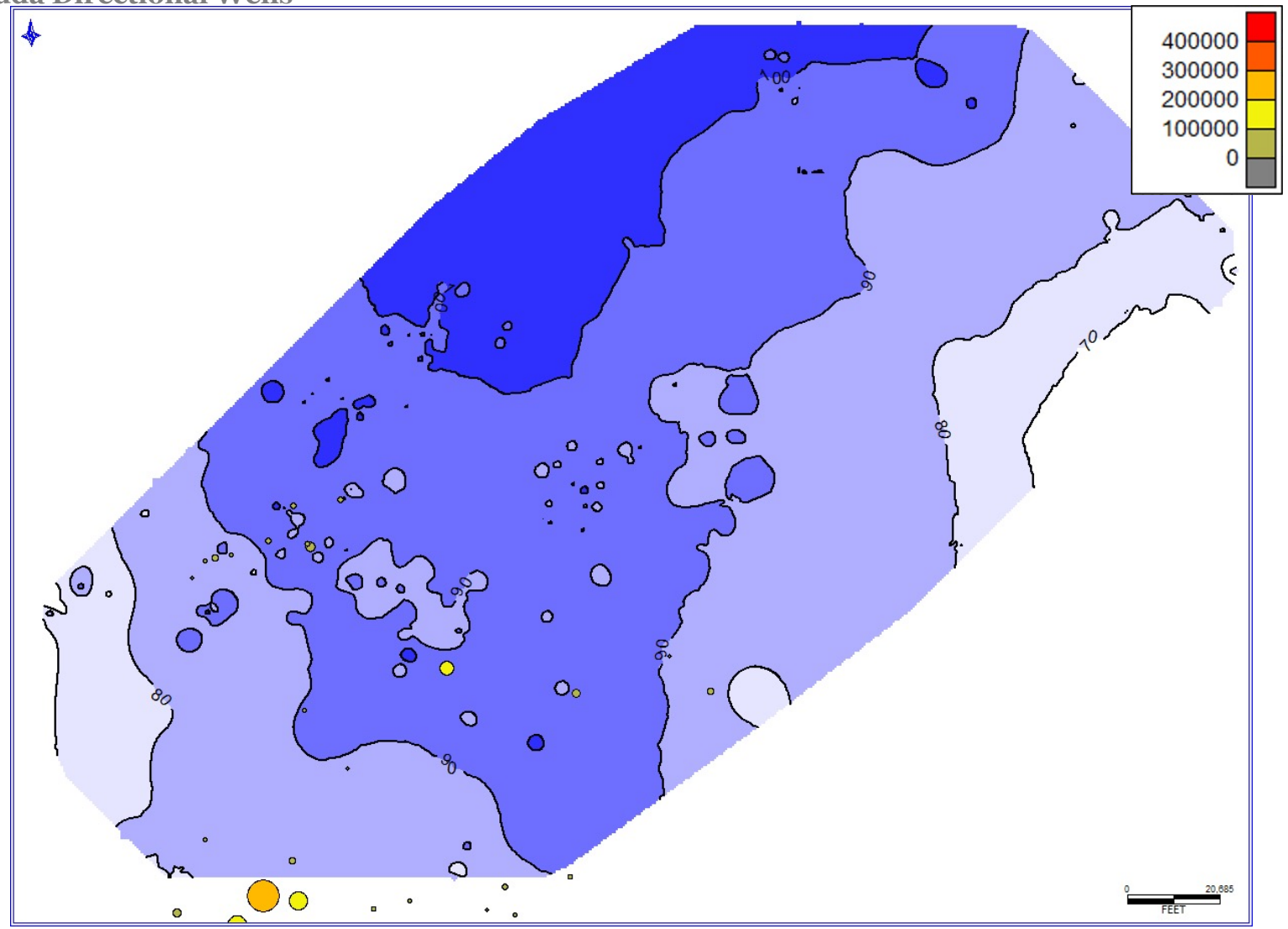
GROSS ISOPACH

Buda; CUMOIL 1 Year; Buda Directional Wells





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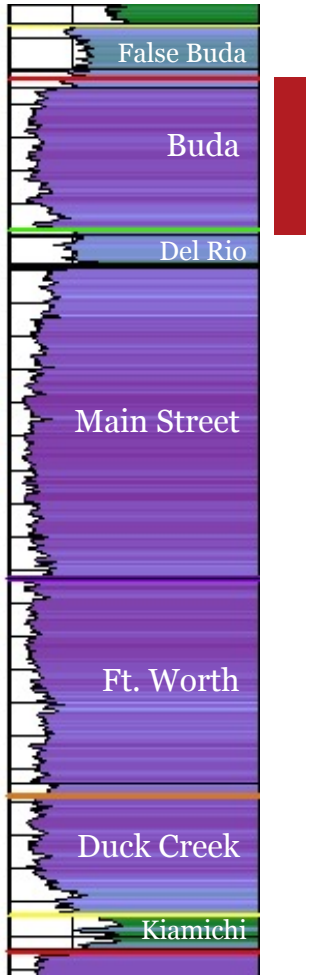
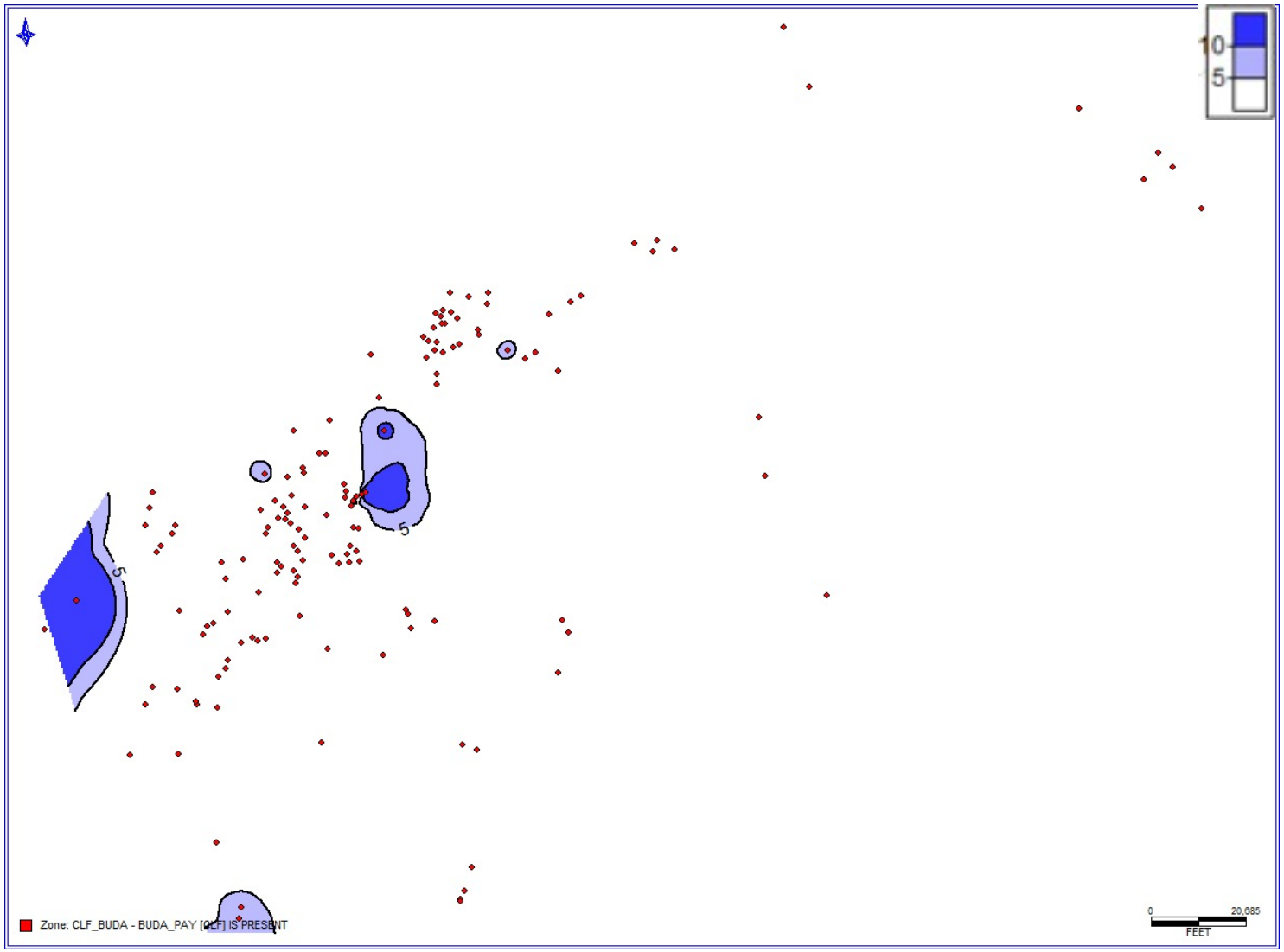
NET ISOPACH

Buda





Gamma Ray	≤45 API
Density Porosity	≥8%
Density Correction	Between -0.1 & +0.1
Washout	≤2.5” or ≤3.5”

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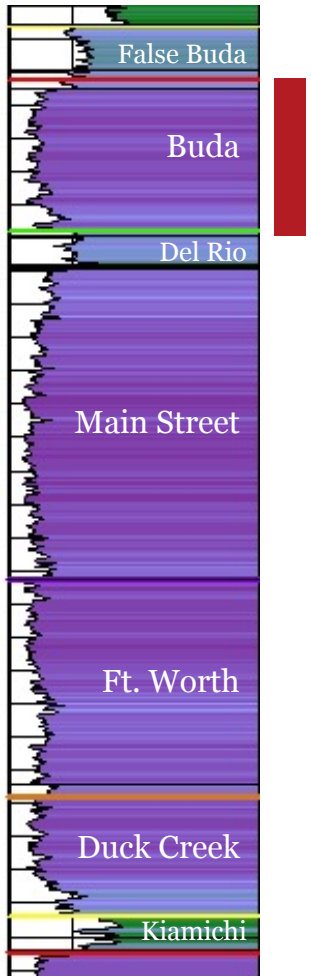
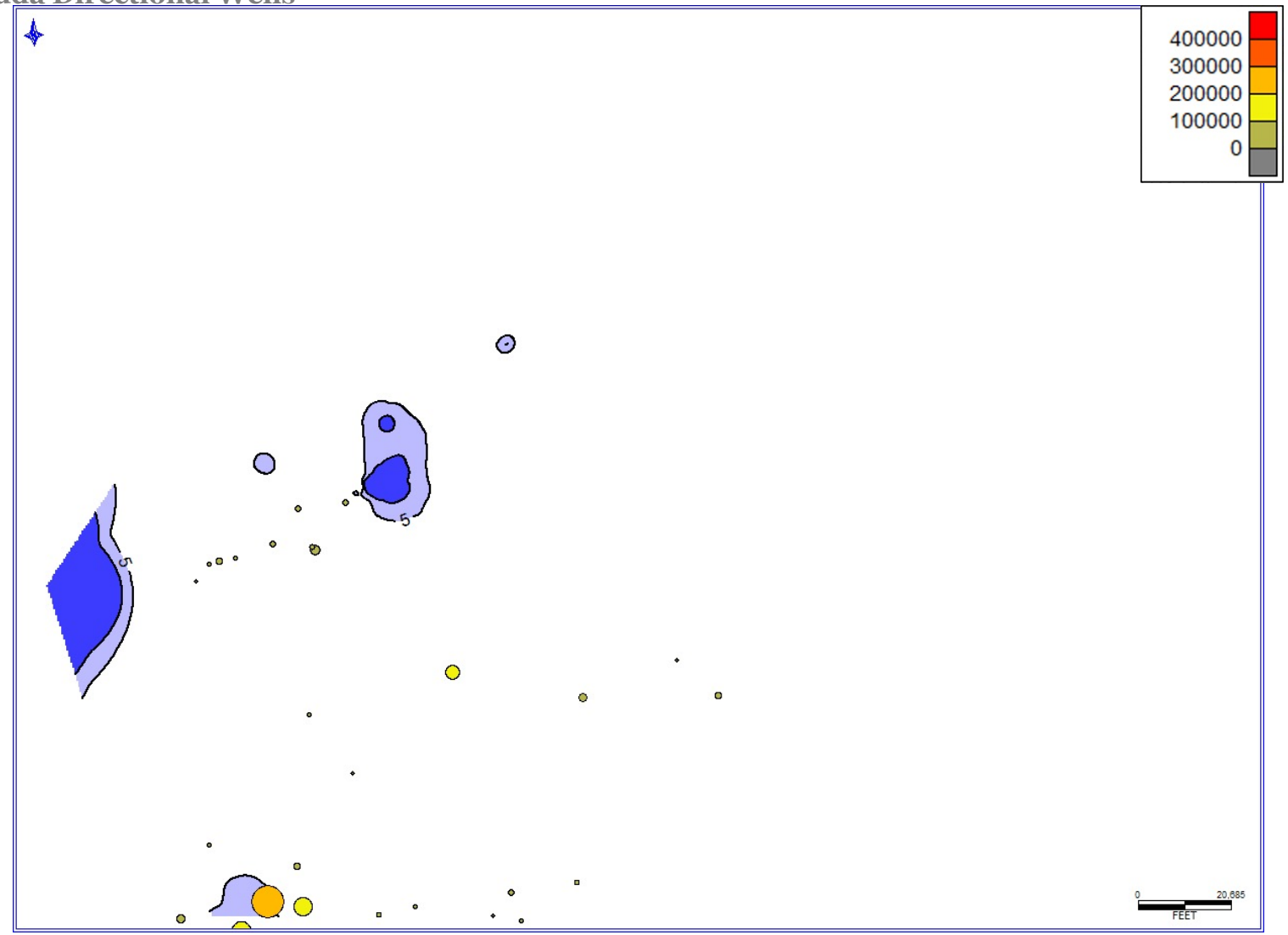
NET ISOPACH

Buda; CUMOIL 1 Year; Buda Directional Wells





Gamma Ray	≤45 API
Density Porosity	≥8%
Density Correction	Between -0.1 & +0.1
Washout	≤2.5” or ≤3.5”

CONCLUSIONS I

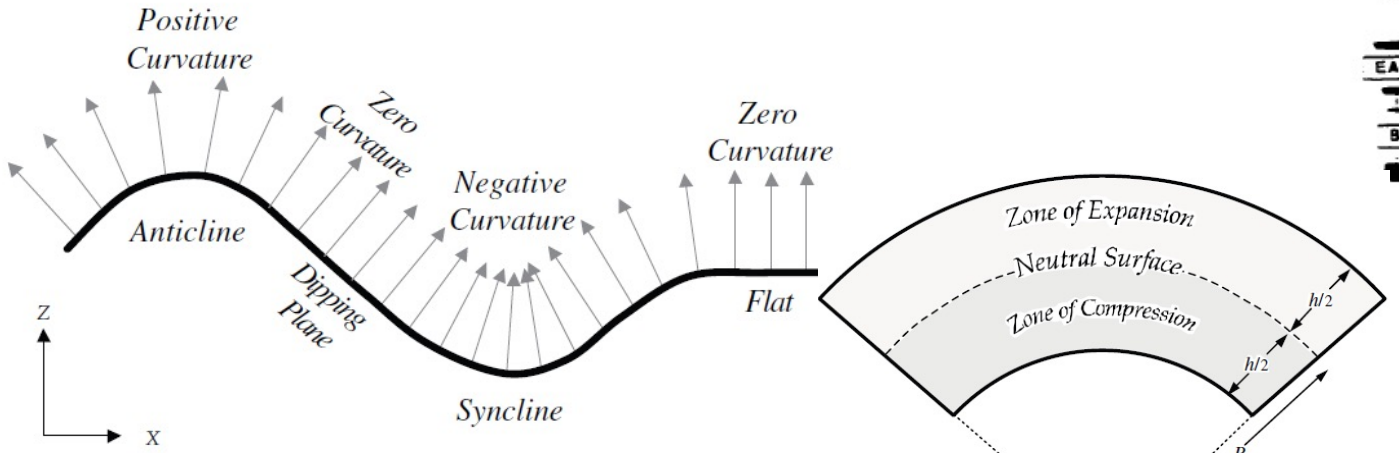
- Poor correlation between net isopach maps and production.
  - Poor well spacing near producing localities.
  - Only 6 producing wells contain logs viable for picking pay.
  - Washout is a consistent problem across the study area within target zones.
  - Reservoirs are likely natural fracture driven rather than matrix porosity driven.
  - Experimentation with different well log cutoff parameters yields similar results (LAS files only).

- Additional methods for identifying naturally fractured areas are needed.

FRACTURE FORMATION HYPOTHESES

Fracturing within the Buda and Georgetown could be attributed to:

1) flexure in the formations due to subsidence from Tertiary overburden. *(Parker, 2000)*
2) flexure in the formations due to the structure of the basement.
3) flexure in the formations due to deeper salt evacuation.
4) overpressure and expulsion of hydrocarbons from adjacent source rocks (Eagle Ford, Del Rio) due to maturation.



(Roberts, 2001)

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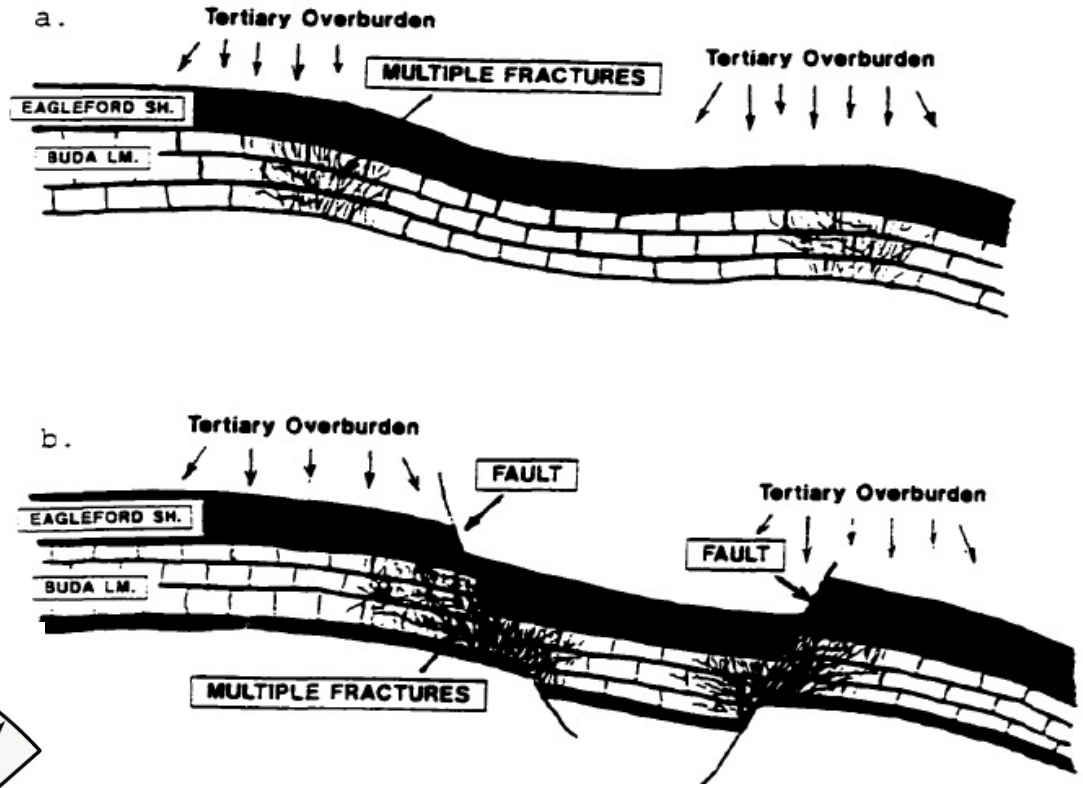
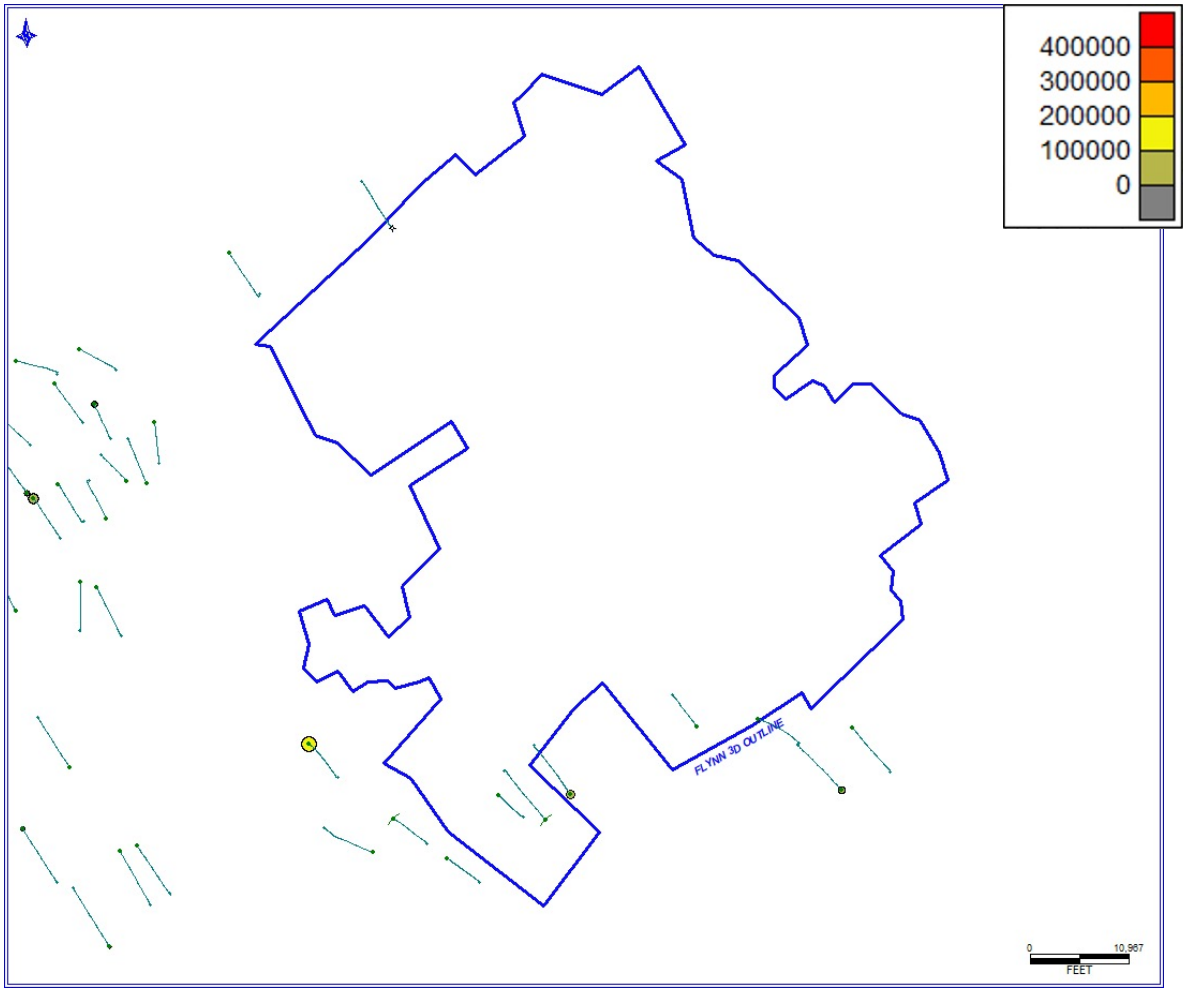


(Parker, 2000)

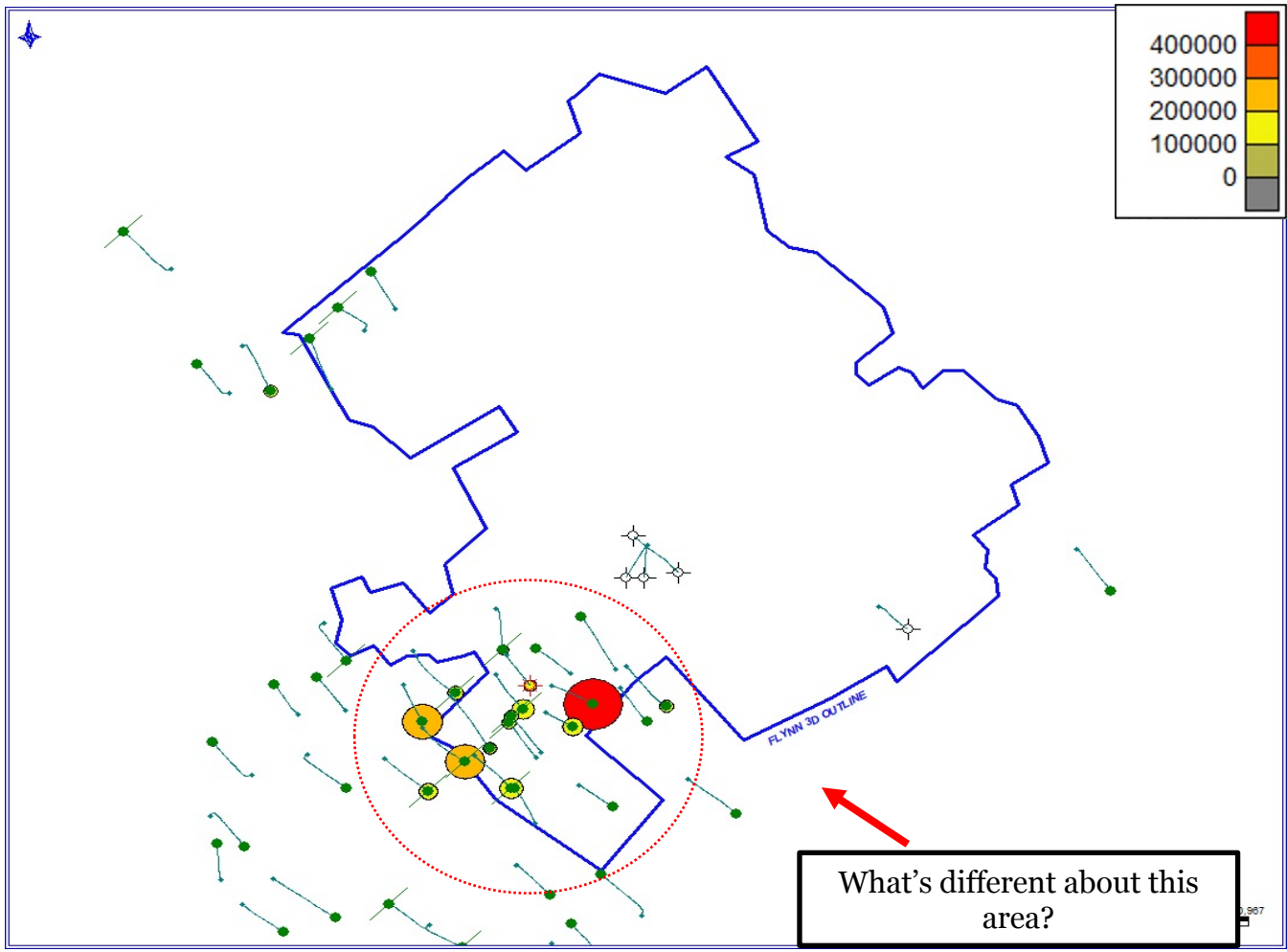
See **APPENDIX A** for additional methodology

SEISMIC OVERVIEW (SEISMIC REMOVED)

CUMOIL 1 Year, Buda Directional



CUMOIL 1 Year, Georgetown Directional



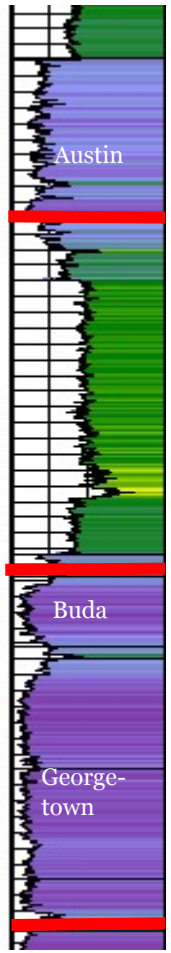
SEISMIC OVERVIEW (SEISMIC REMOVED)

Similarity Map

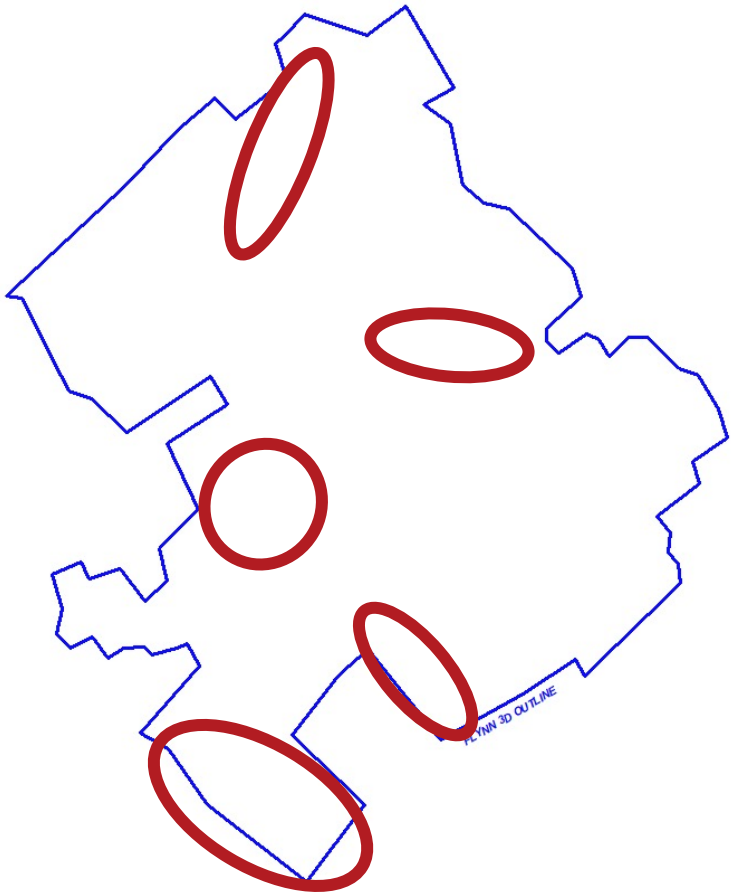
Base of Austin

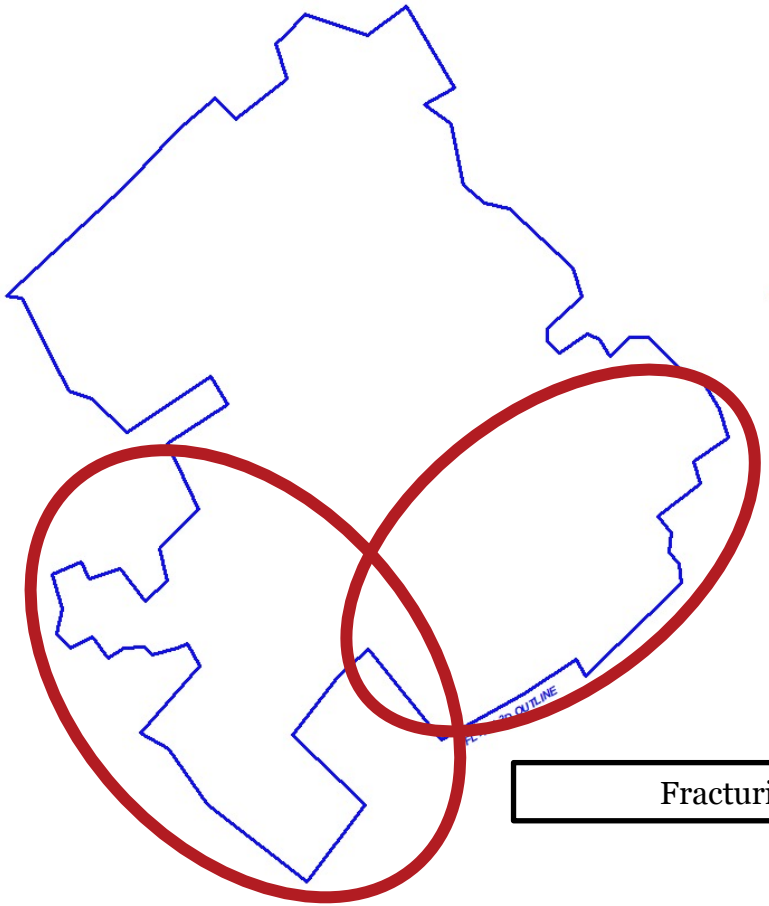
Buda

Goodland

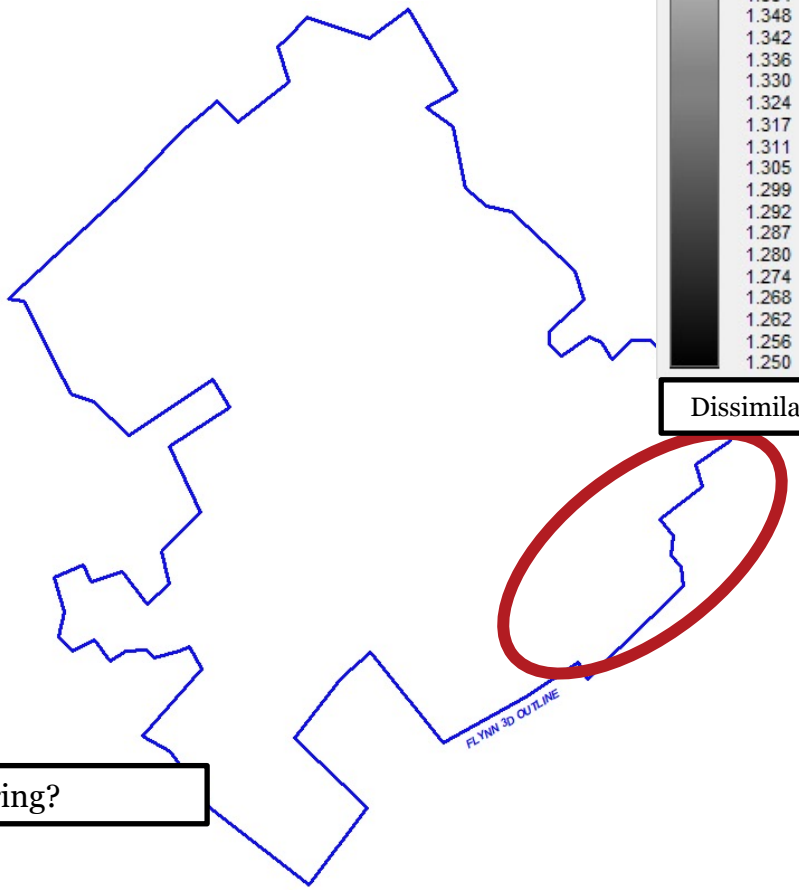


Goodland





Fracturing?



Similar

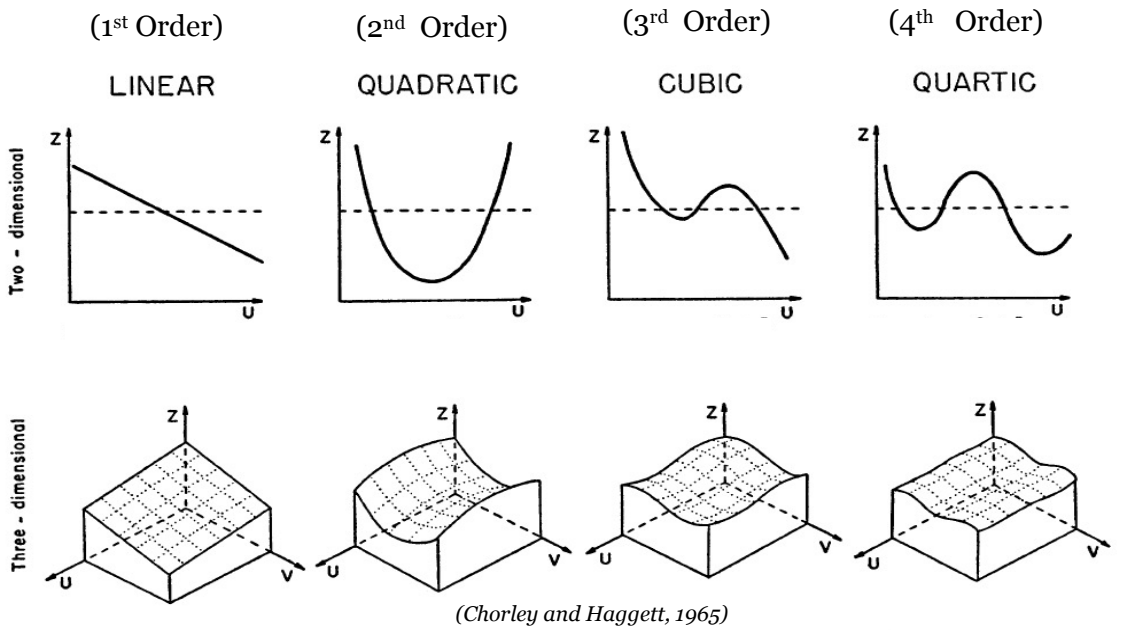
1.410
1.404
1.397
1.391
1.385
1.379
1.372
1.367
1.360
1.354
1.348
1.342
1.336
1.330
1.324
1.317
1.311
1.305
1.299
1.292
1.287
1.280
1.274
1.268
1.262
1.256
1.250

Dissimilar

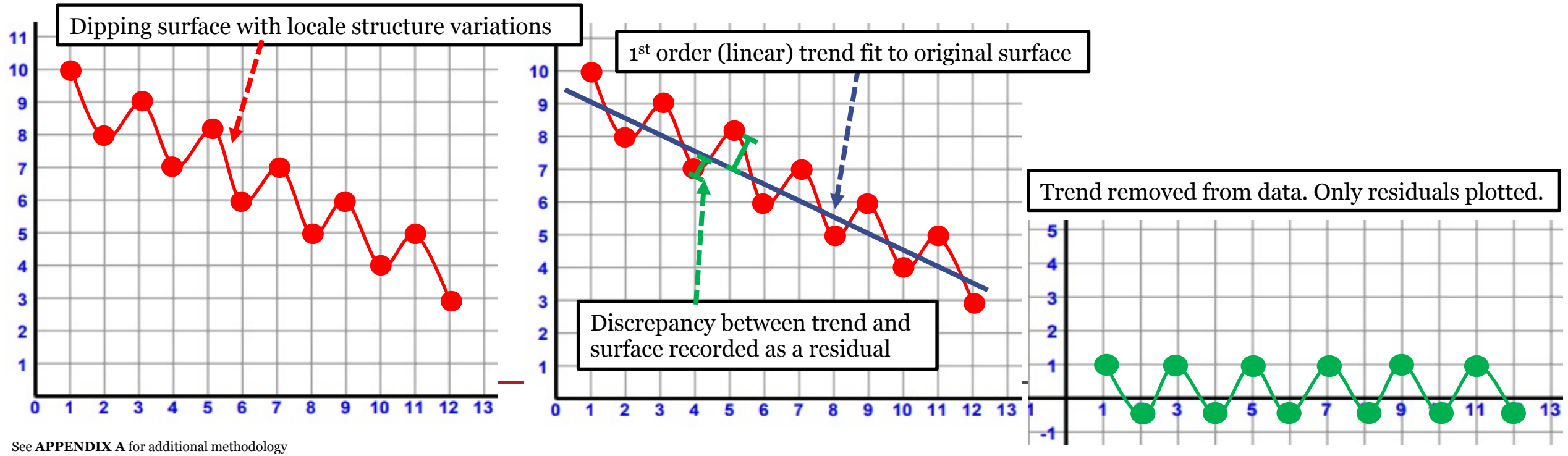
RESIDUAL TREND MAP METHODOLOGY

- The residual trend map accentuates local variations in structure that might otherwise be overshadowed by the regional trend.
- Trends above cubic (3rd order) are often not considered because they fit the true structural surface too well to show local variations. *(Frank Hernandez, Covey Park Energy, Personal Comm., 2019)*

Seismic horizons are integrated with well data structure maps to create the residual trend maps.



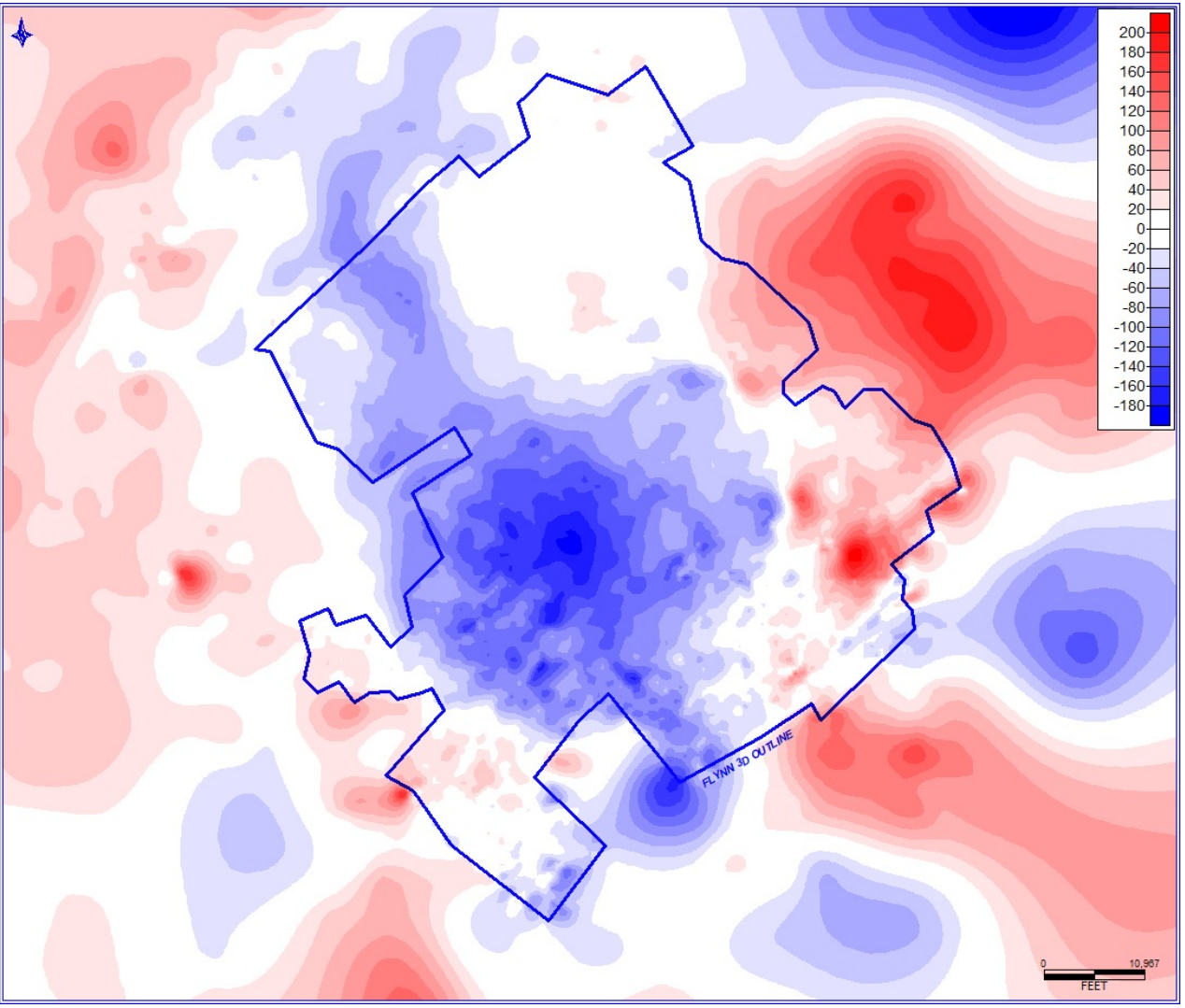
(Chorley and Haggett, 1965)



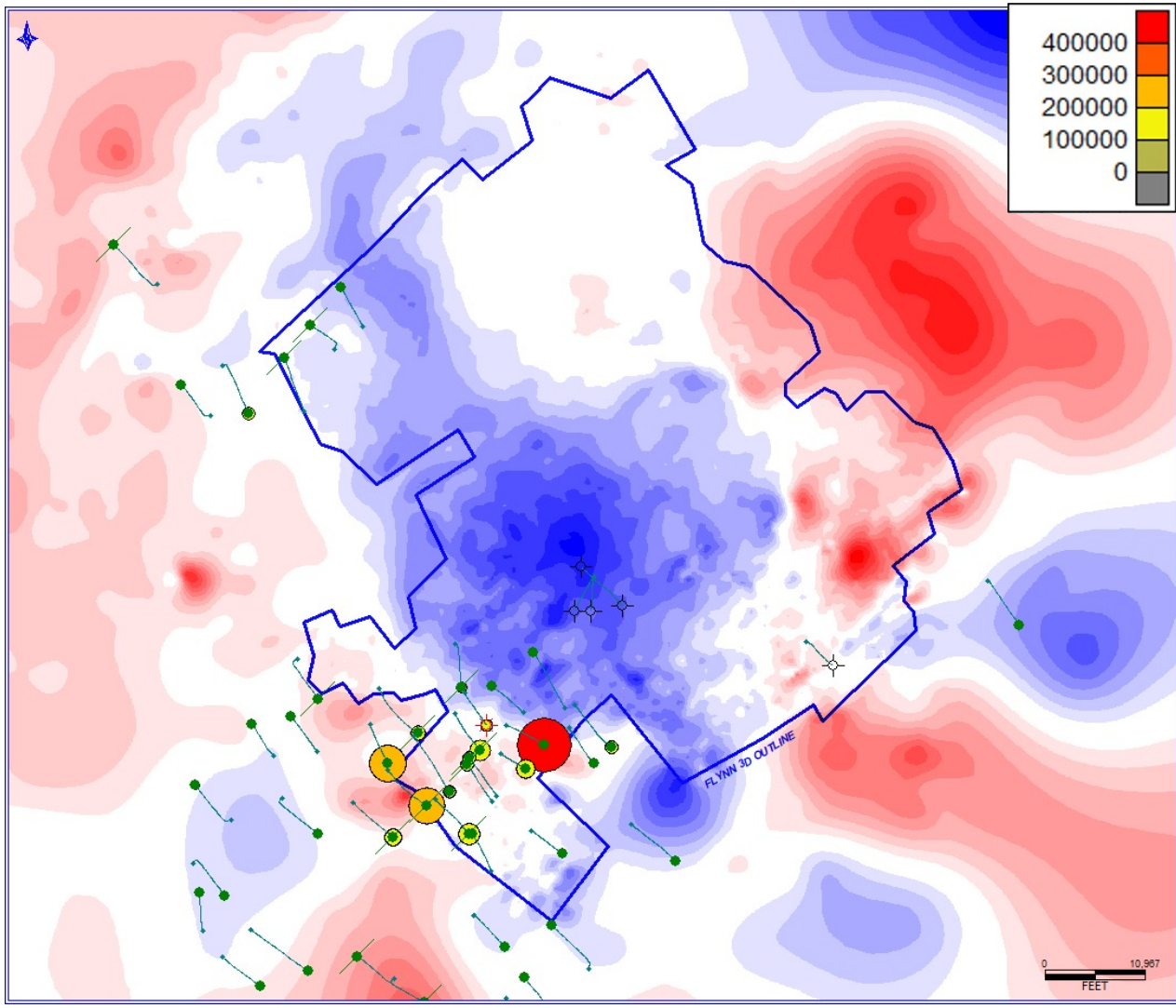
See **APPENDIX A** for additional methodology

3RD ORDER RESIDUAL TREND

Buda

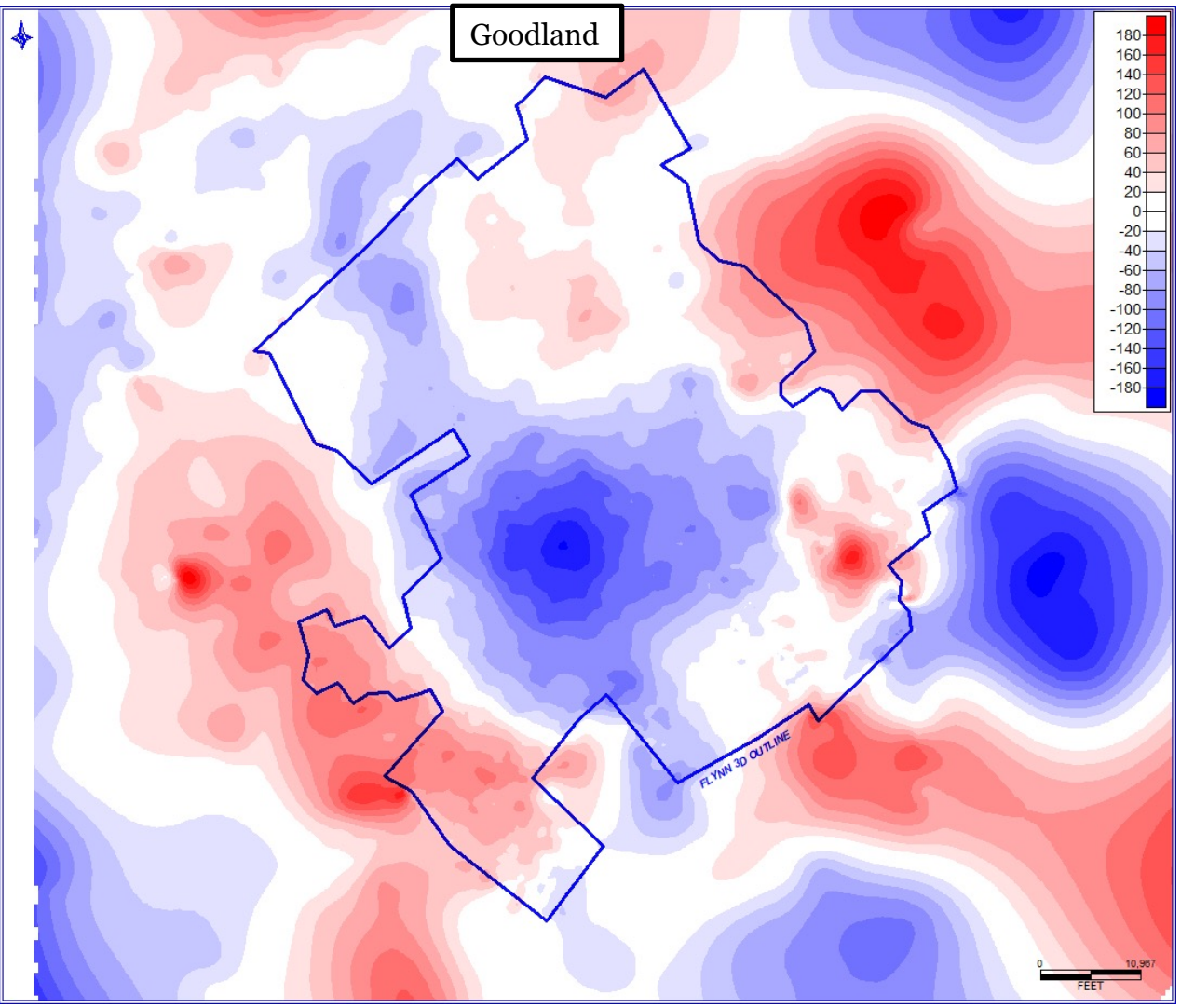


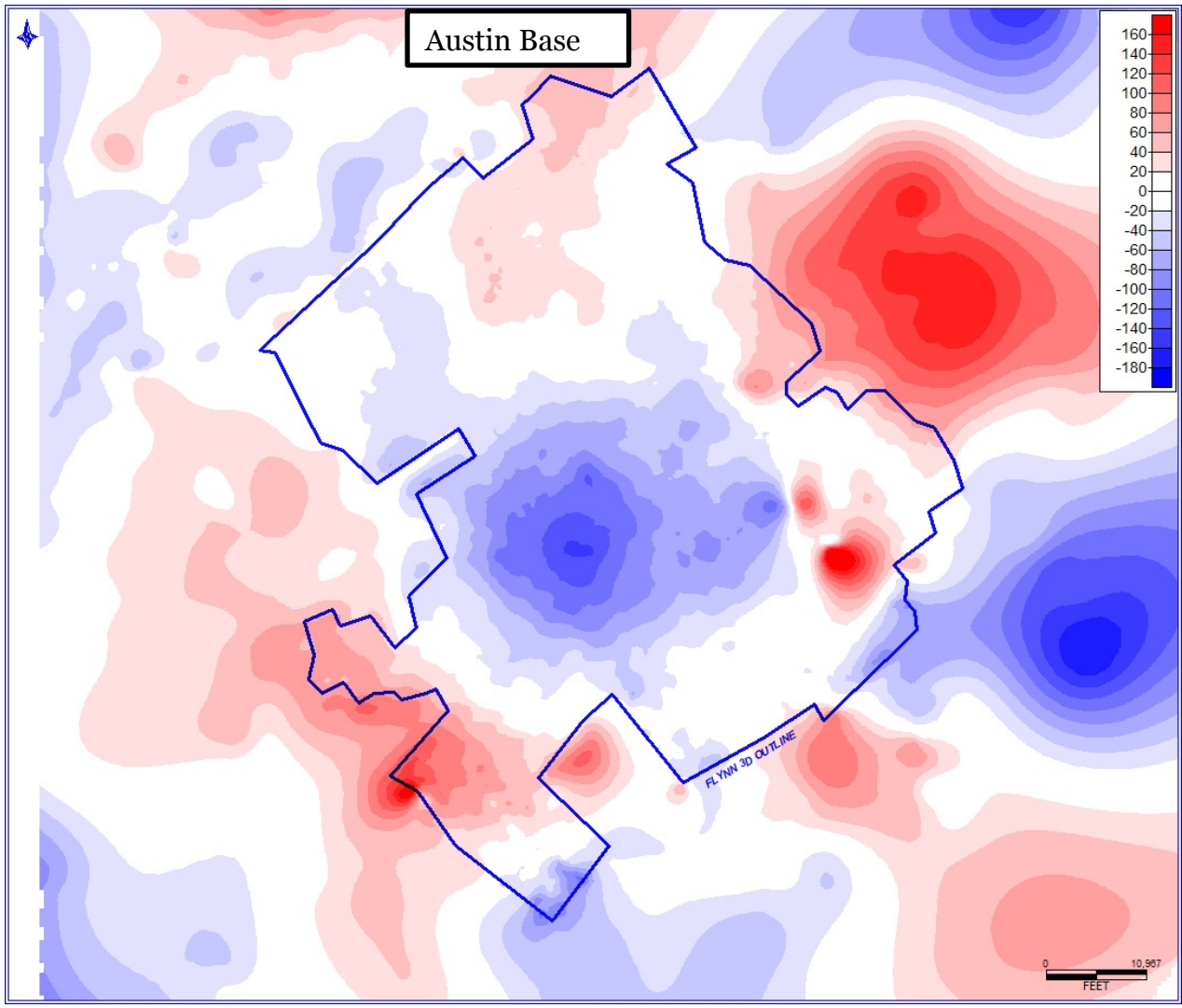
CUMOIL 1 Year, Georgetown Directional Production



3RD ORDER RESIDUAL TREND

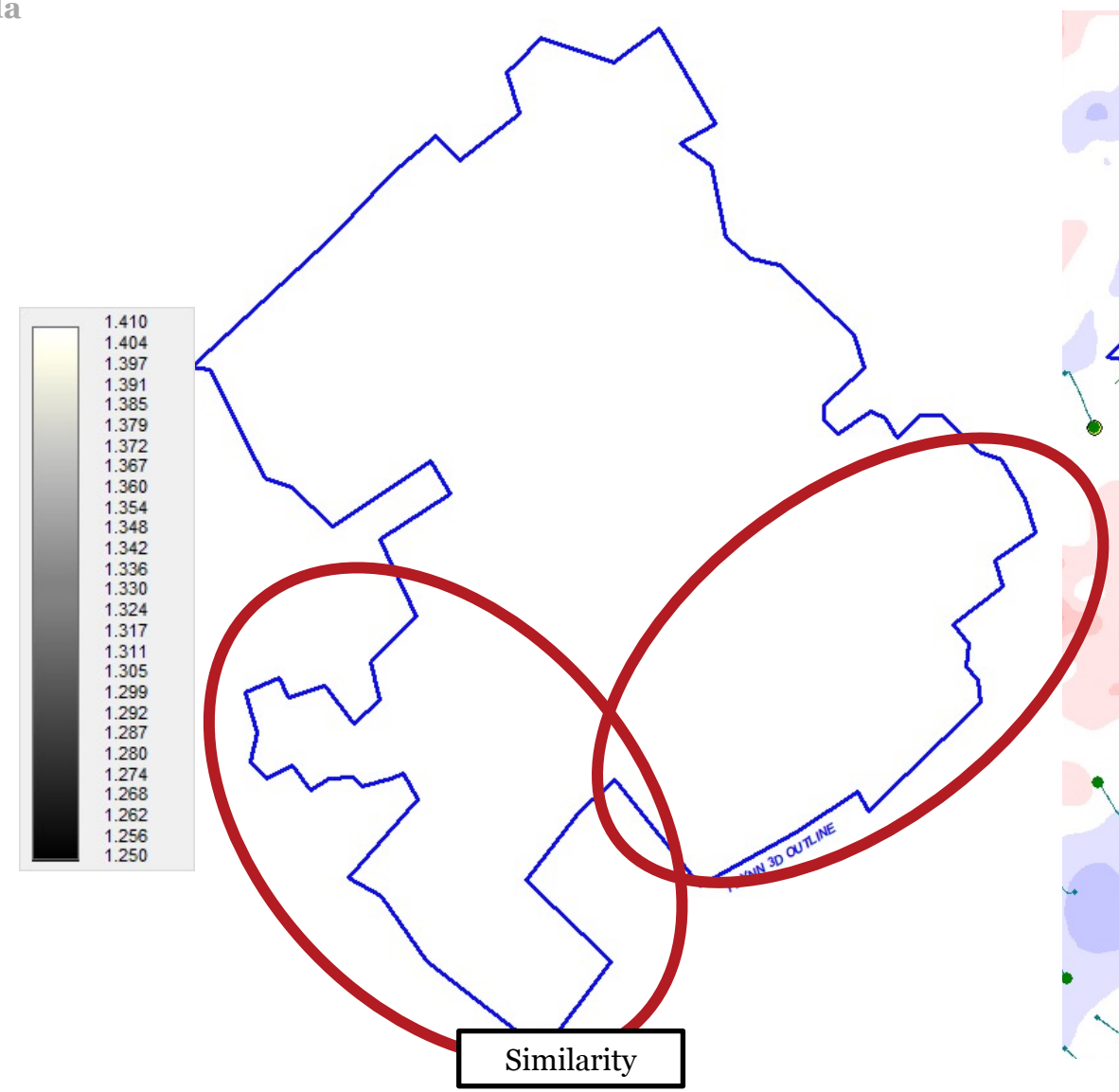
CUMOIL 1 Year, Georgetown Directional Production



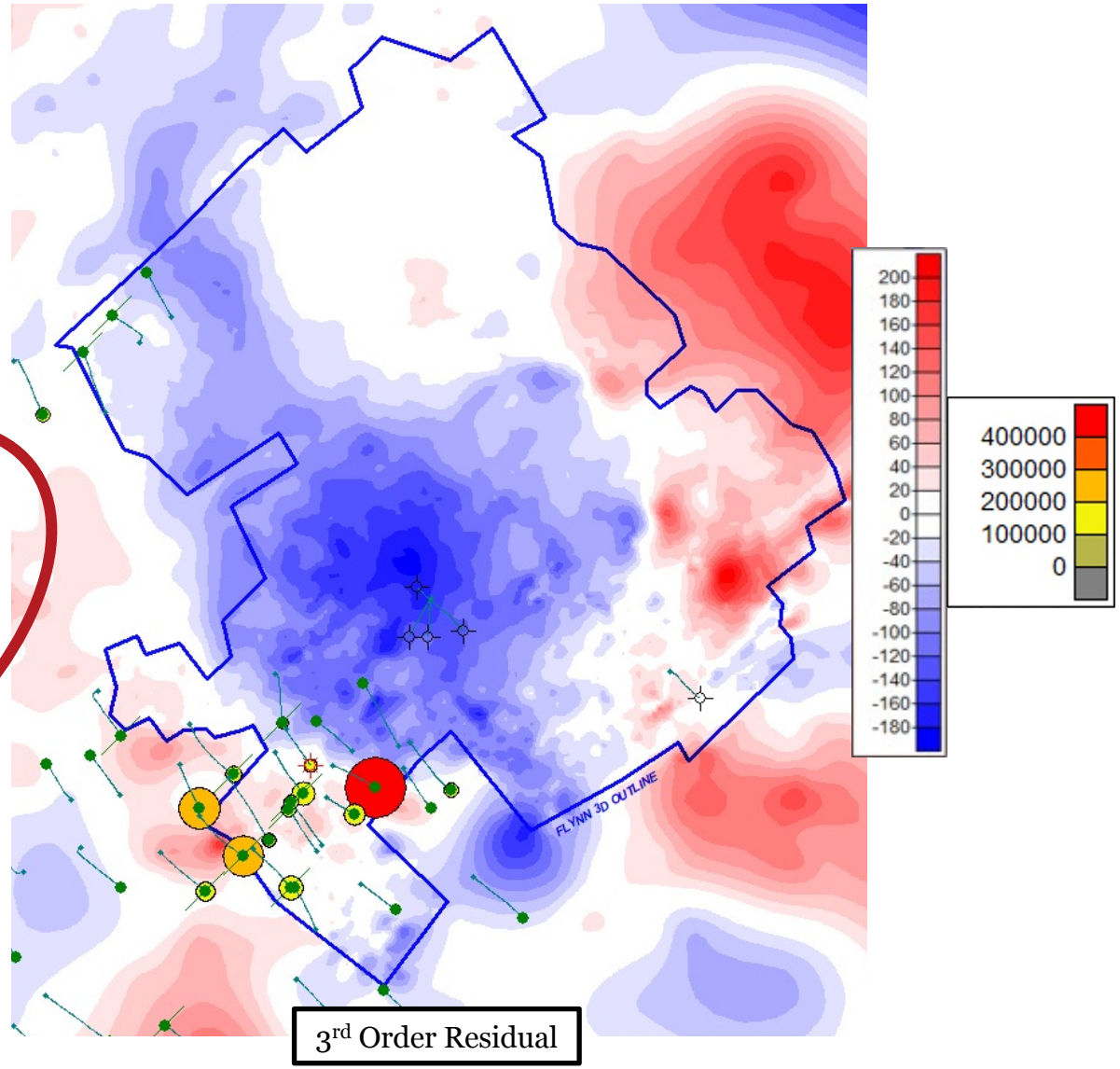


3RD ORDER RESIDUAL TREND (SEISMIC REMOVED)

Buda



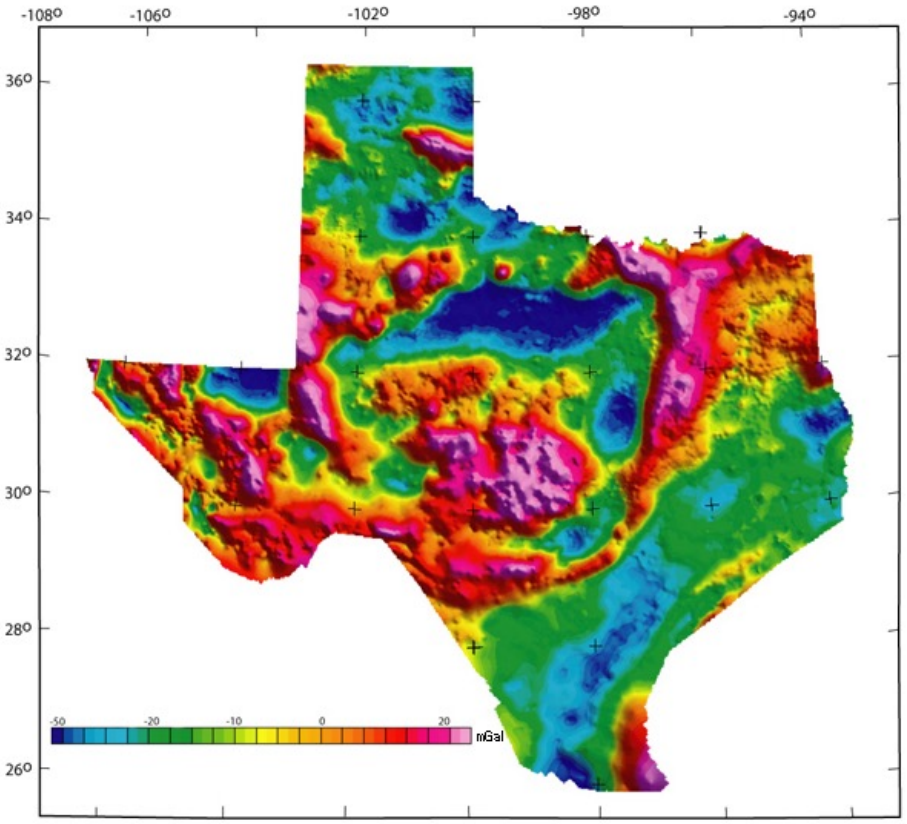
Similarity



3rd Order Residual

GRAVITY

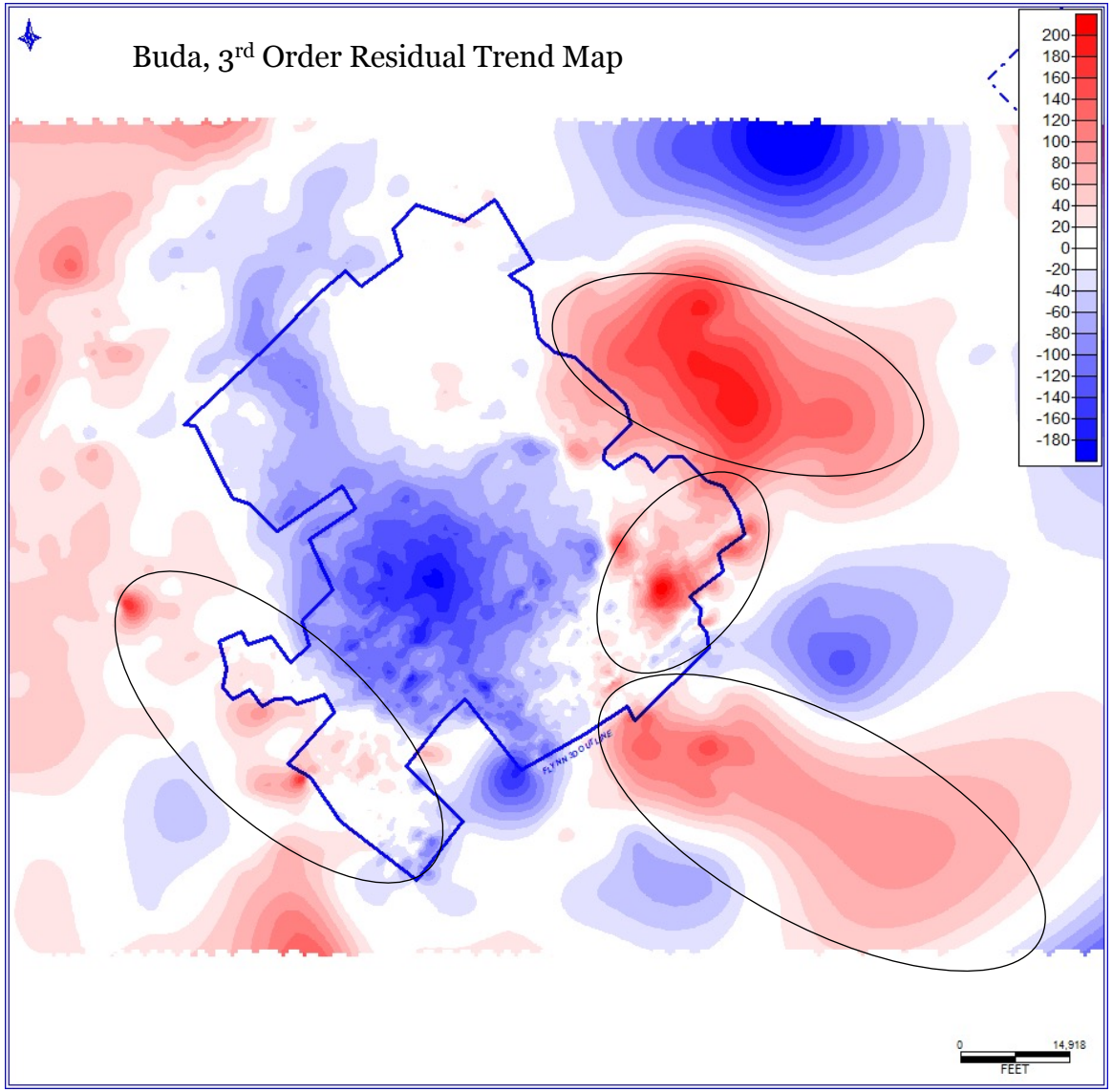
Isostatic Residual Gravity

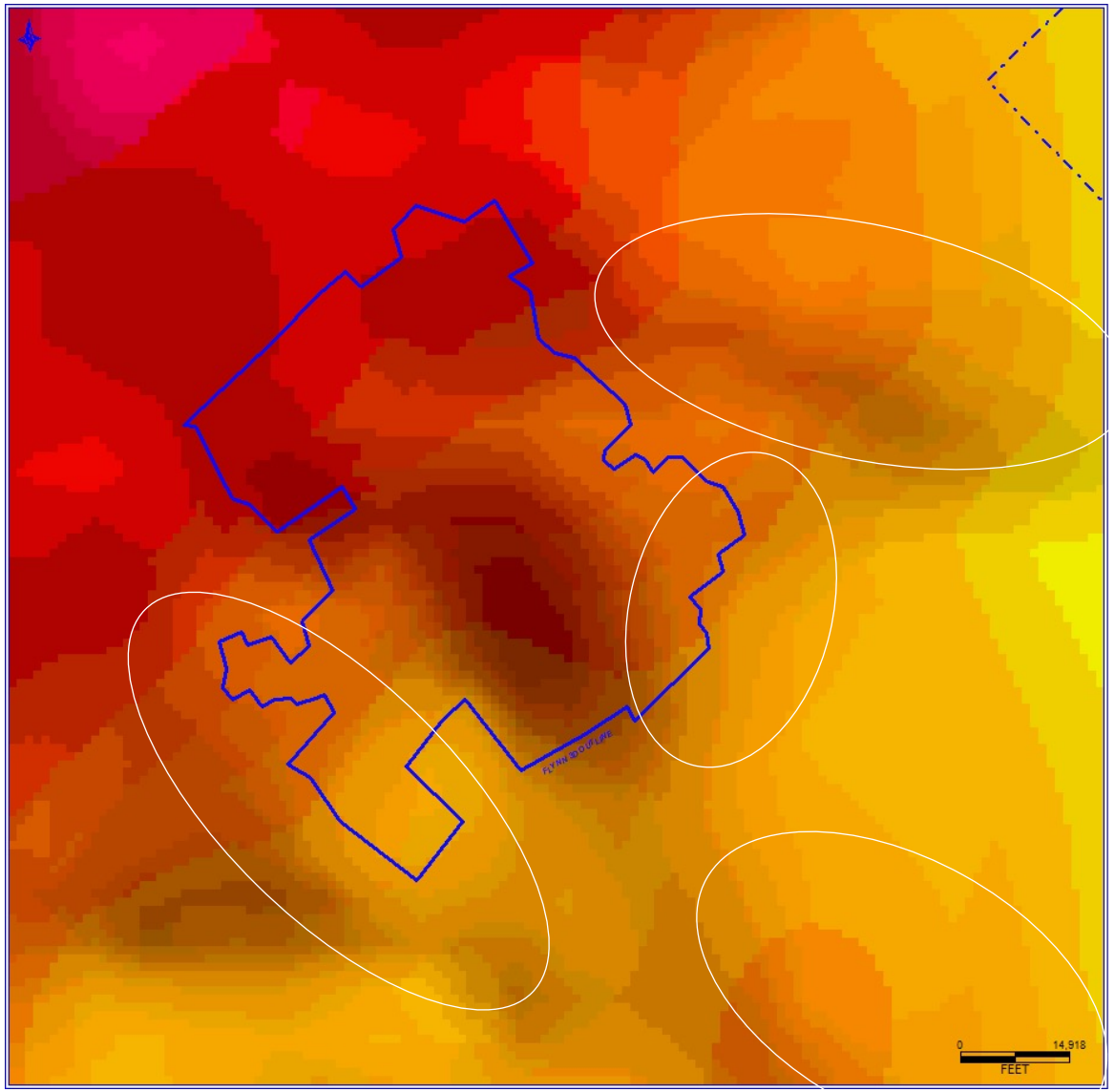


https://pubs.usgs.gov/ds/2006/232/texas_iso.htm

See Appendix C for aeromagnetic anomaly and additional gravity maps

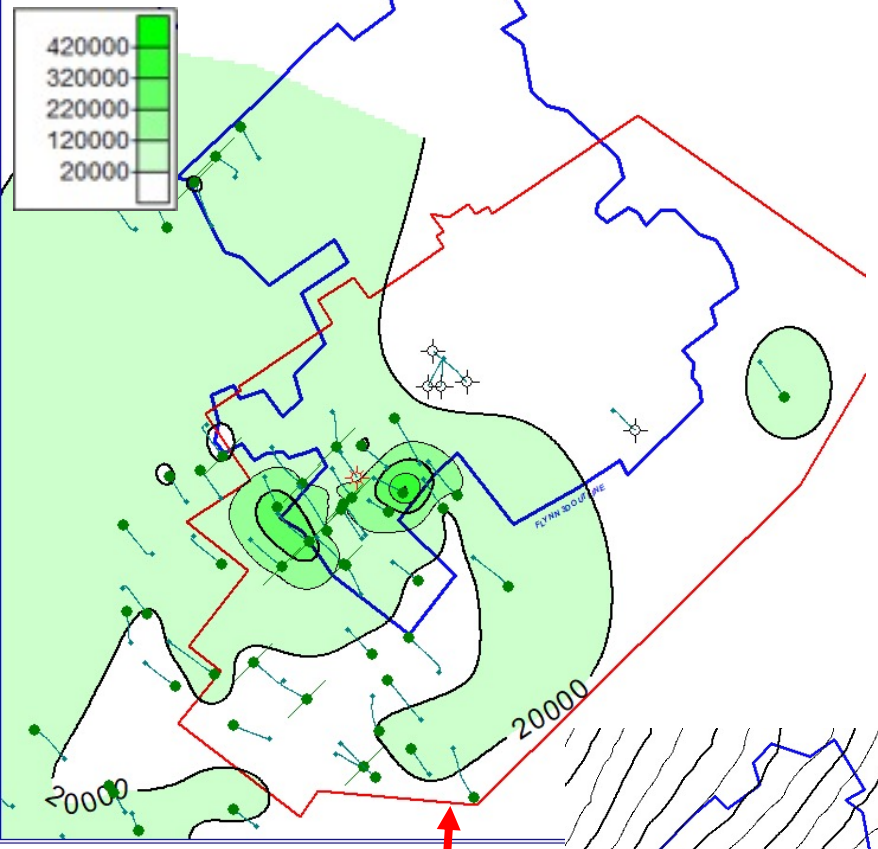
ISOSTATIC RESIDUAL GRAVITY





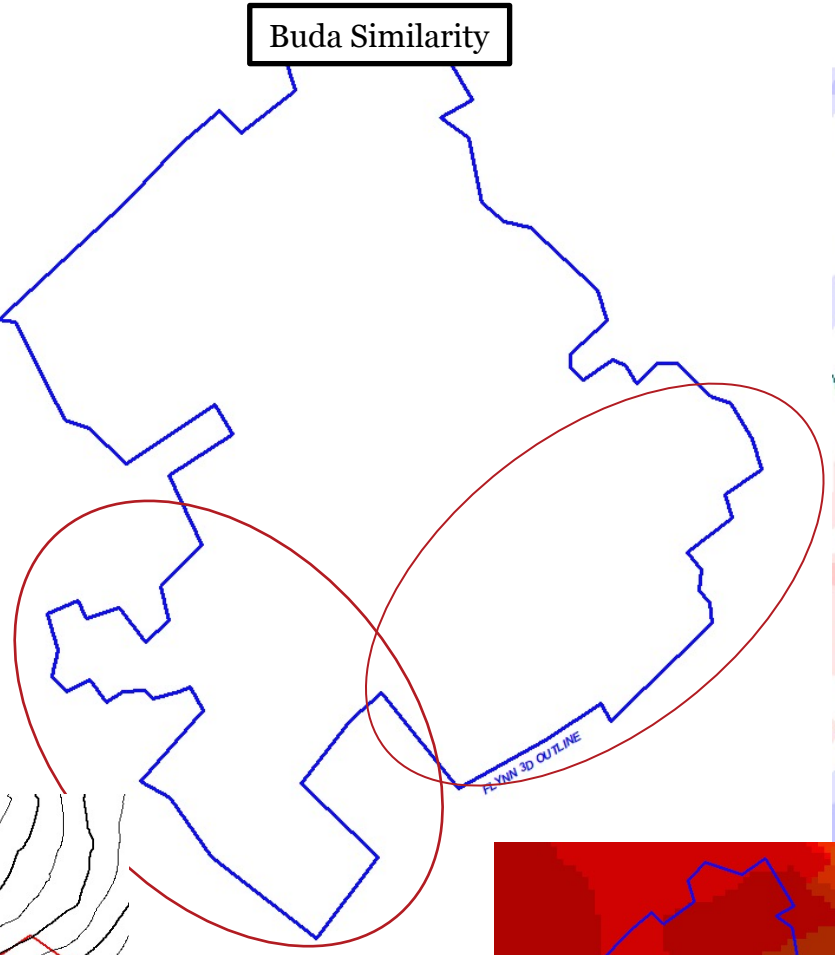
Residual trend maps controlled by basement structure?

CUMOIL 1 Year (bbl) – Georgetown Directional Wells

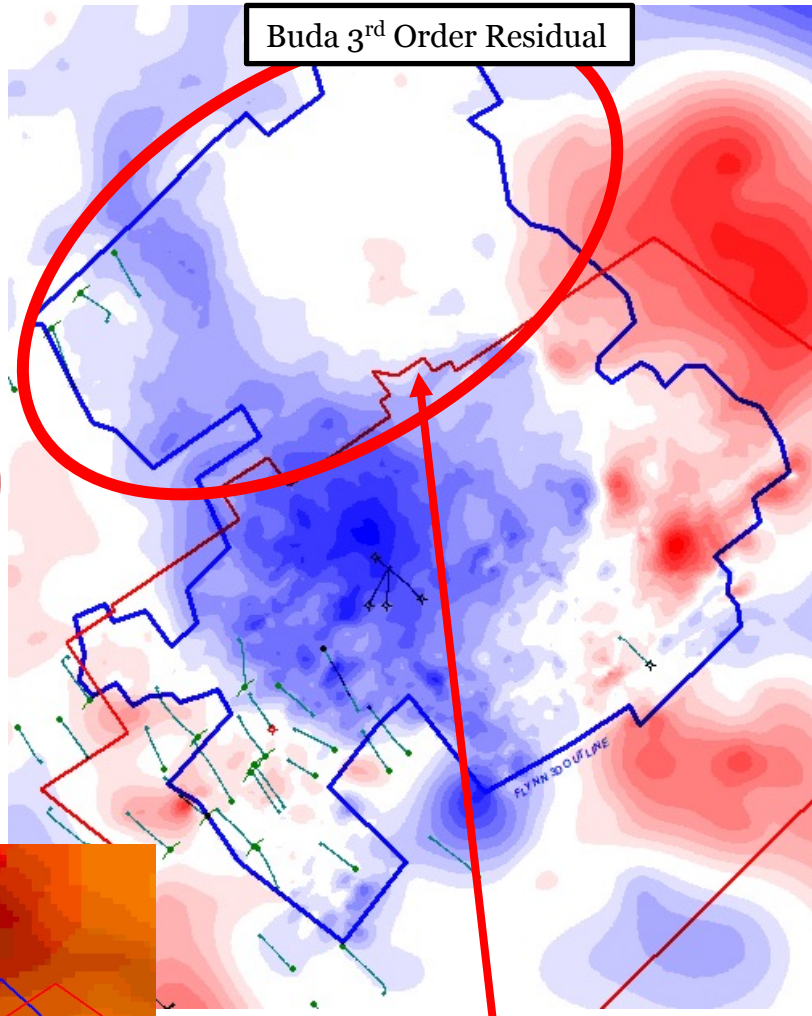


No mineral rights above the Kiamichi Shale

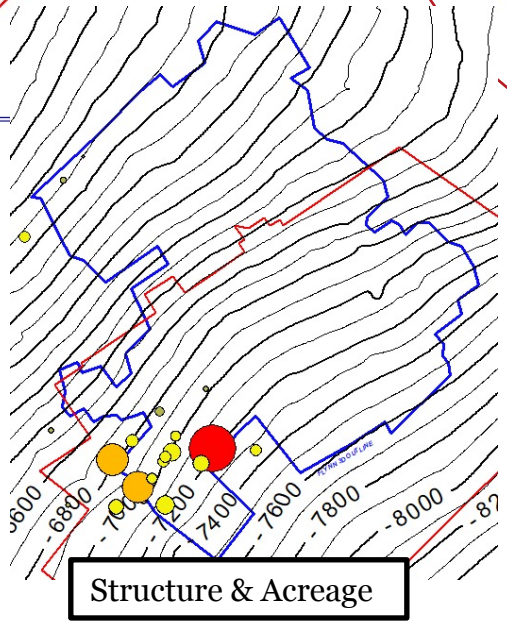
Buda Similarity



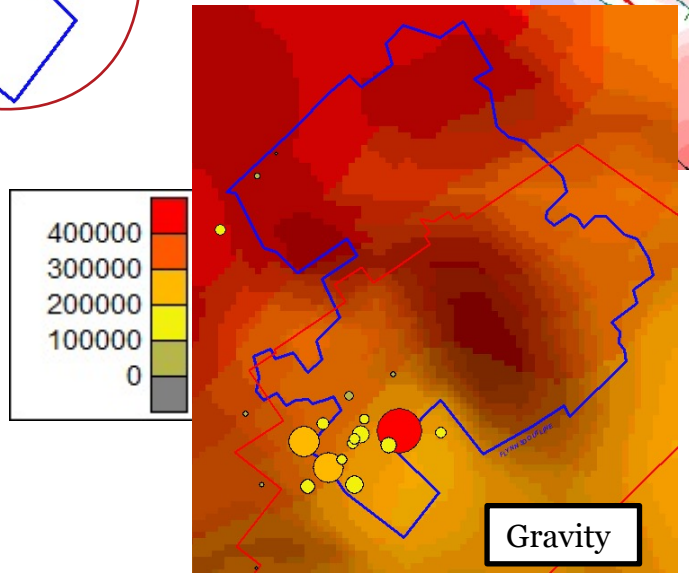
Buda 3rd Order Residual



- Poor production in NW
- Flat or negative local structure
- Limited evidence of fracturing



Structure & Acreage



Gravity

CONCLUSIONS II

- Seismic data exhibits dissimilarity (poor coherence) within the Buda and Georgetown in association with producing fields which may indicate fracturing.

- Third order residual trend maps reveal correlation between positive structural features in the Buda and Georgetown and production. Flexure associated with these structures may be linked to natural fracturing.

- Third order residual trend maps suggest local structural features are projected through the sub-surface, thus fracturing in the Buda and Georgetown is likely due to its relative brittleness.

- Isostatic gravity maps suggest the basement controls local structure and subsequent flexure throughout the studied stratigraphy.

- The Buda and Georgetown within Covey Park Energy acreage appear to exhibit flat or negative local structure with limited evidence of fracturing. Targeting these formations is not recommended.

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APPENDICES

Appendix A – Additional Methodology

Appendix B – Additional Structure & Isopach Maps

Appendix C – Magnetic Maps and Additional Gravity Maps

Appendix D – Salt Diapirs

Appendix E – Additional Local Production Charts

Appendix F – Additional Cross Sections

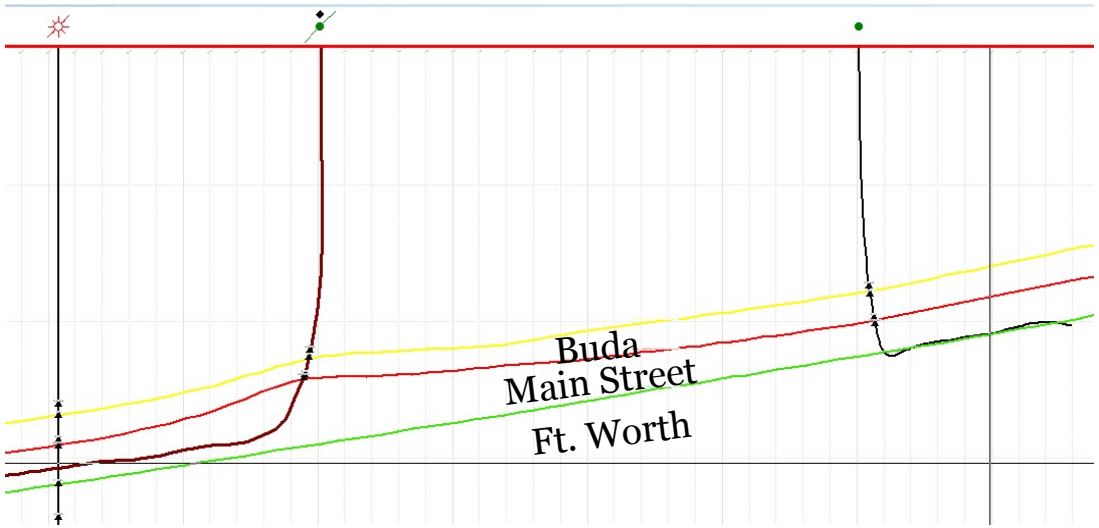
Appendix G – Additional Residual Maps

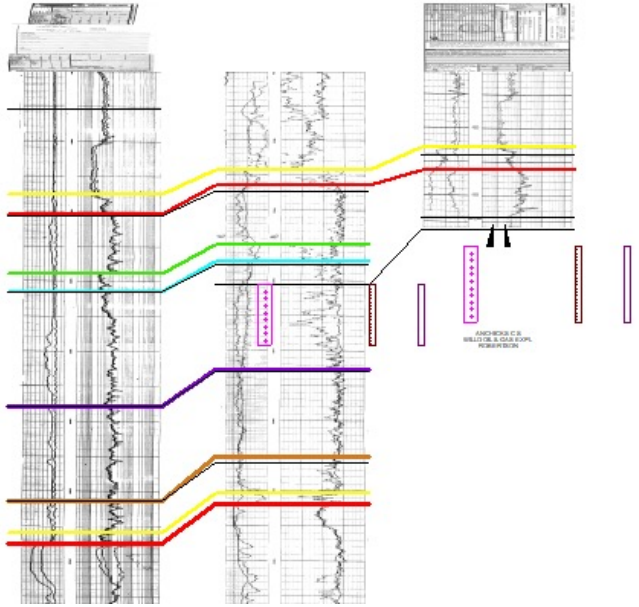
Appendix H – Additional Curvature Maps

APPENDIX A

LOCAL PRODUCTION

- Each producing well's target zone used in this study is manually verified in Petra via the directional well module or cross section.





METHODOLOGY

Structure & Gross Isopach Maps

Structure Maps

—Tops picked on all wells with viable logs within study area (~812 wells)

—Both raster & LAS logs utilized

—Eagleford and Austin Chalk also picked, not used in this study

Gross Isopach

—Only vertical wells with picked tops used in the construction of isopach maps (~612 wells)

Net Isopach

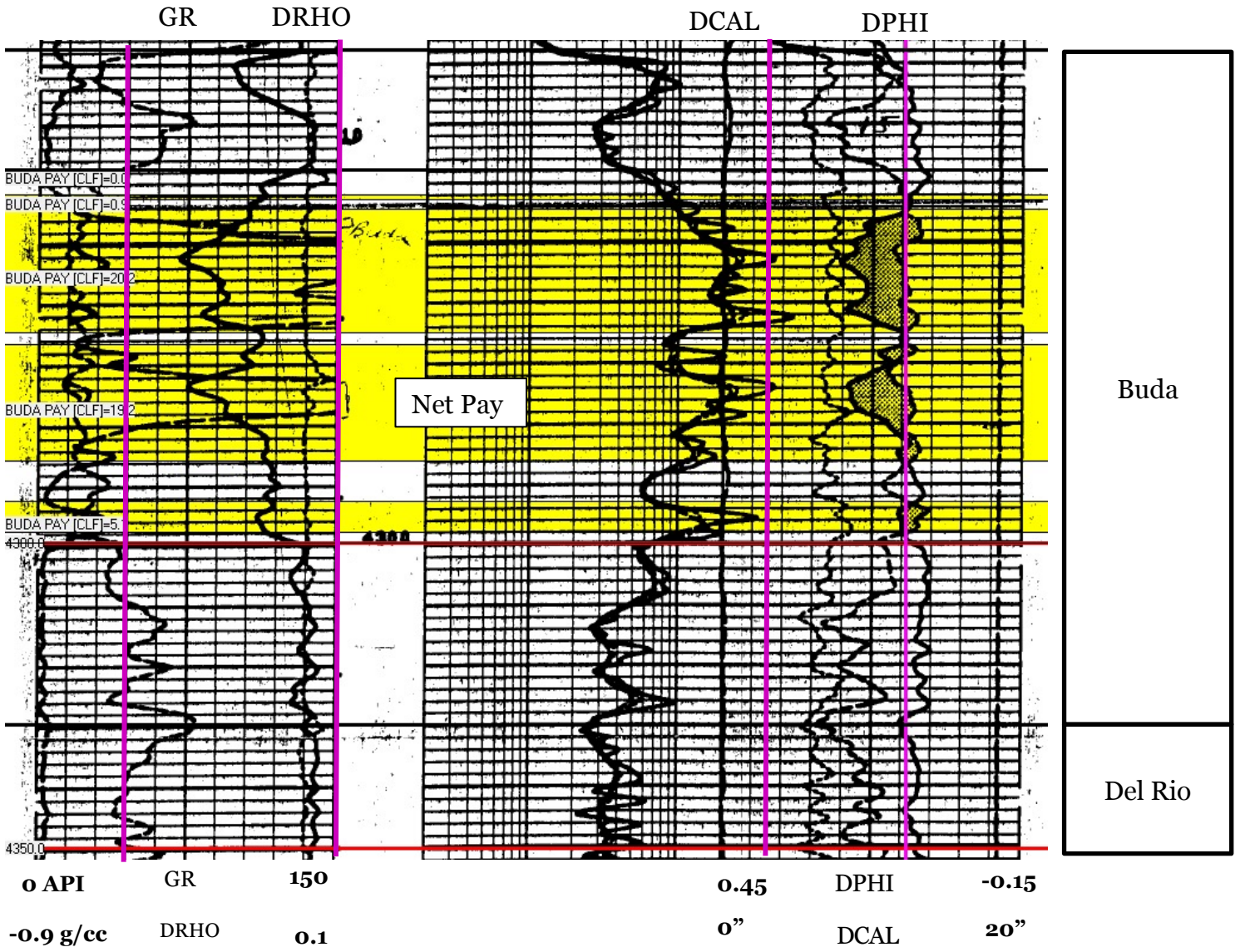
— LAS logs were used to experiment with various other log cutoffs and combinations yielding minimal correlation with producing wells

—Washout maps additionally yielded minimal correlation with producing wells

Gamma Ray	≤45 API (personal discretion)
Density Porosity	≥8% (Snyder & Craft, 1977)
Density Correction	Between -0.1 & +0.1 (Scott Lapierre, Shale Specialist LLC, Personal Comm., 2019)
Washout	≤2.5" or ≤3.5" (personal discretion)

Net Isopach Methodology

- Vertical Well
- Buda Production
- Total CUMOIL: 855 bbl
- Total CUMGAS: 765,284 MCF



METHODOLOGY

Structure & Gross Isopach Maps

Bubble Maps

—Only verified production is used in bubble maps.

—1 Year CUMOIL and 30 Day CUMOIL bubble maps created using directional wells

Curvature Maps

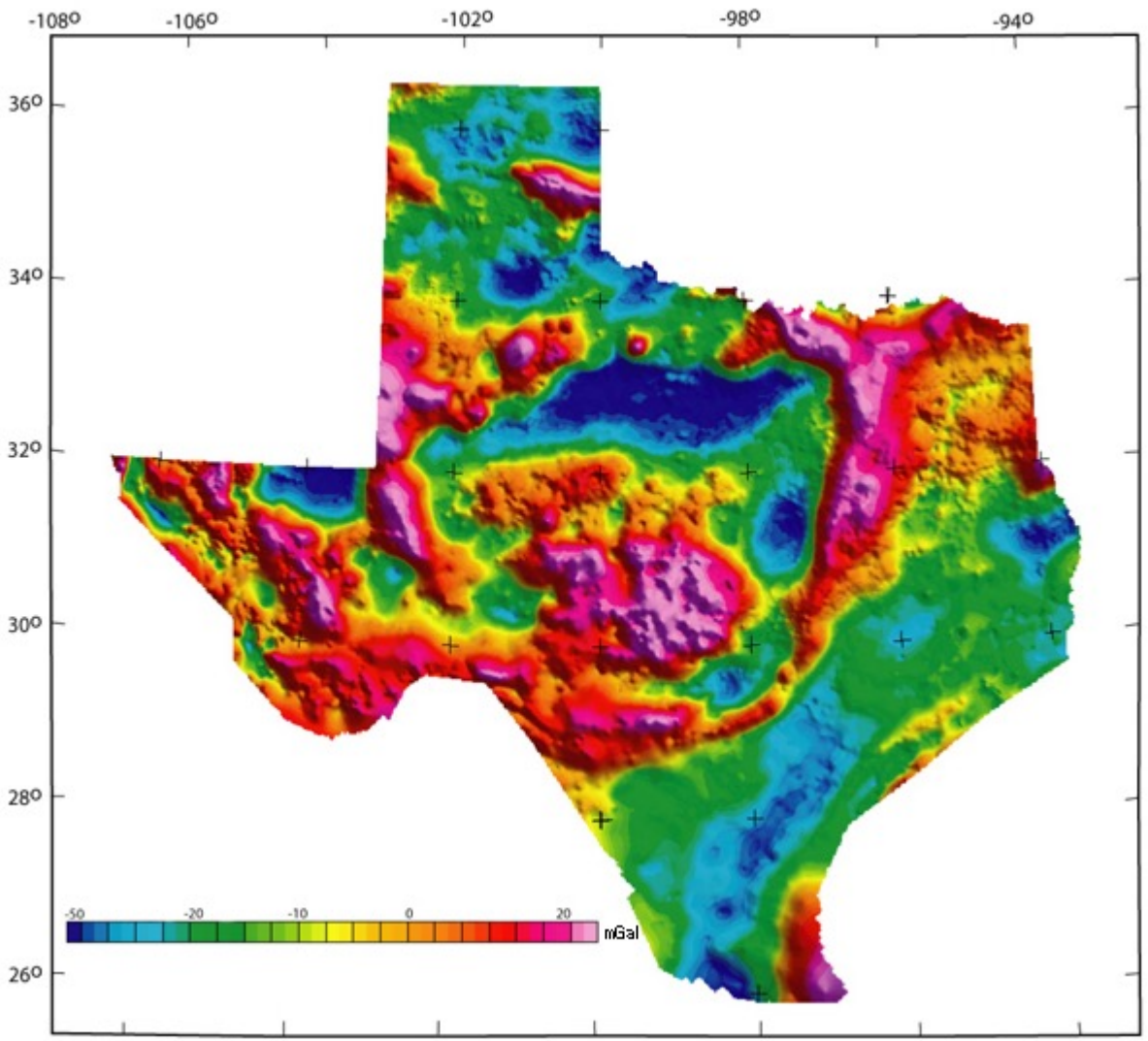
— Curvature maps created from structure grids from picked well log formation tops alone yield large anomalies derived from variations in well spacing.

APPENDIX B

APPENDIX C

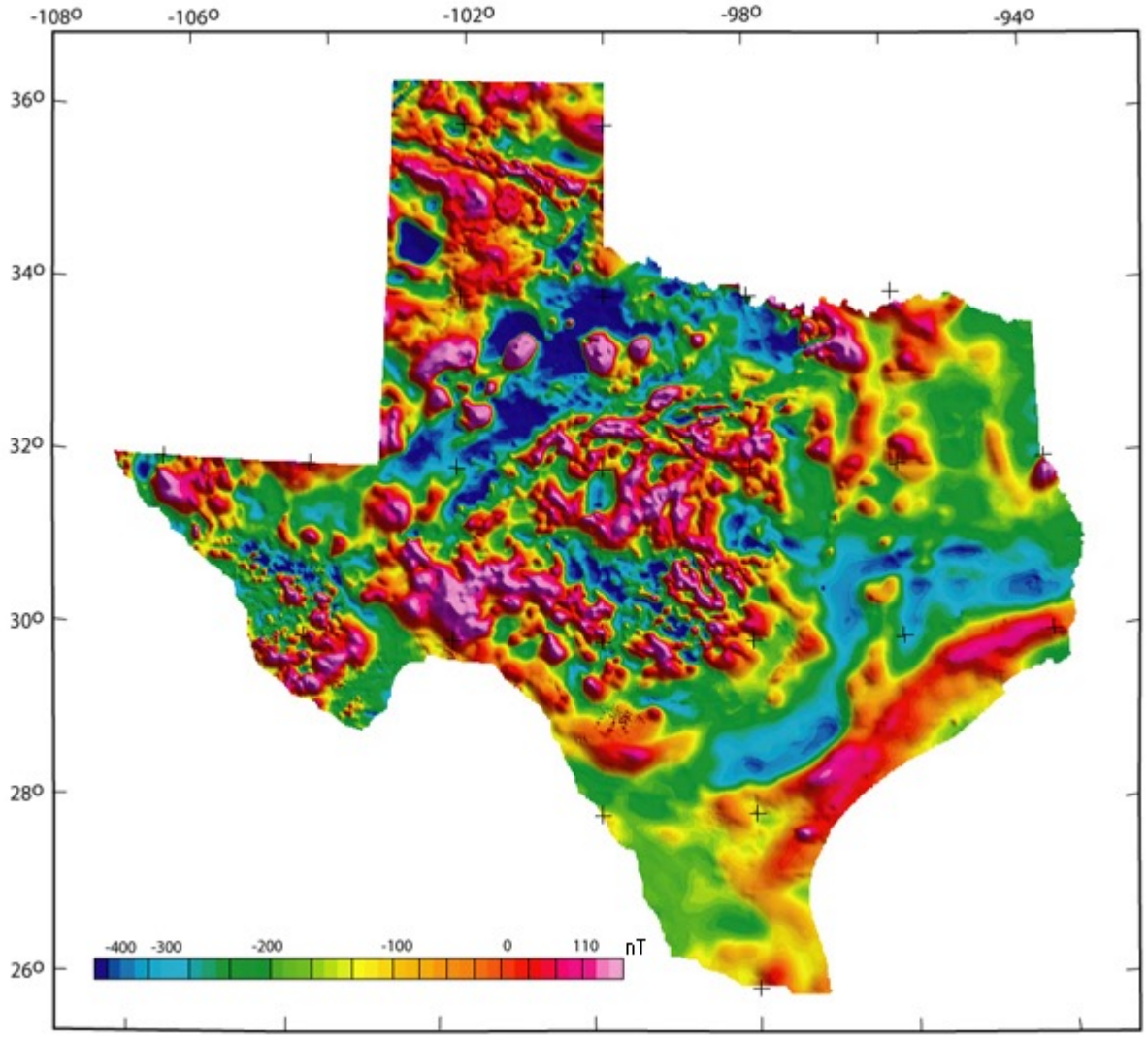
GRAVITY & MAGNETICS

Isostatic Residual Gravity



https://pubs.usgs.gov/ds/2006/232/texas_iso.htm

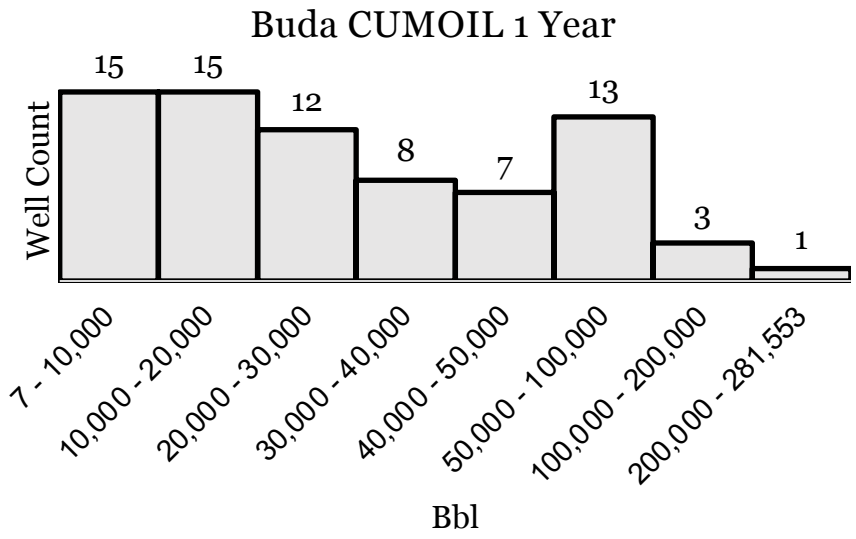
Aeromagnetic Anomalies

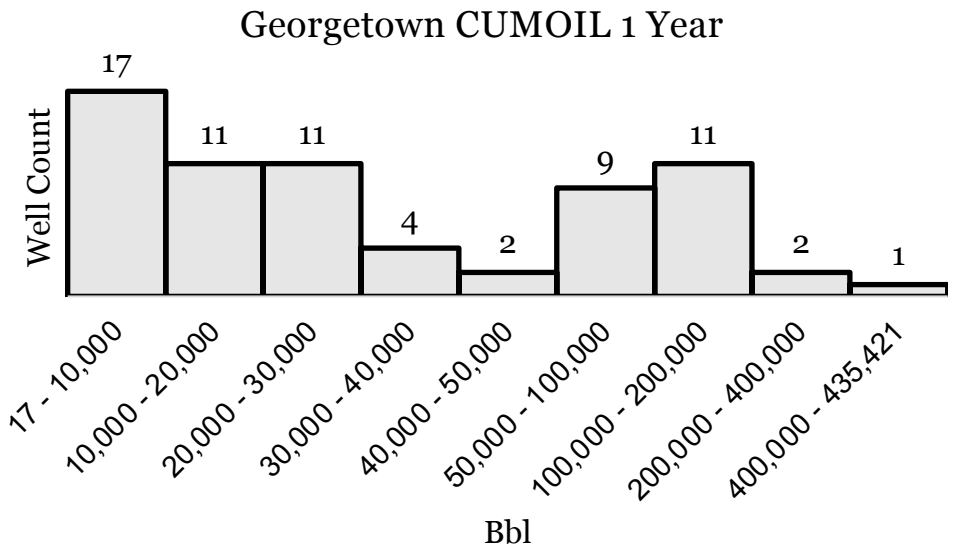


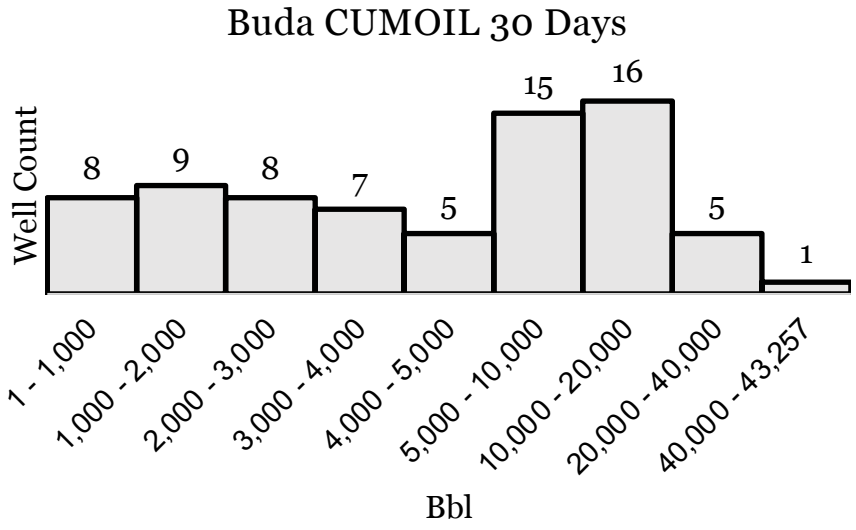
See Appendix C for aeromagnetic anomaly maps.

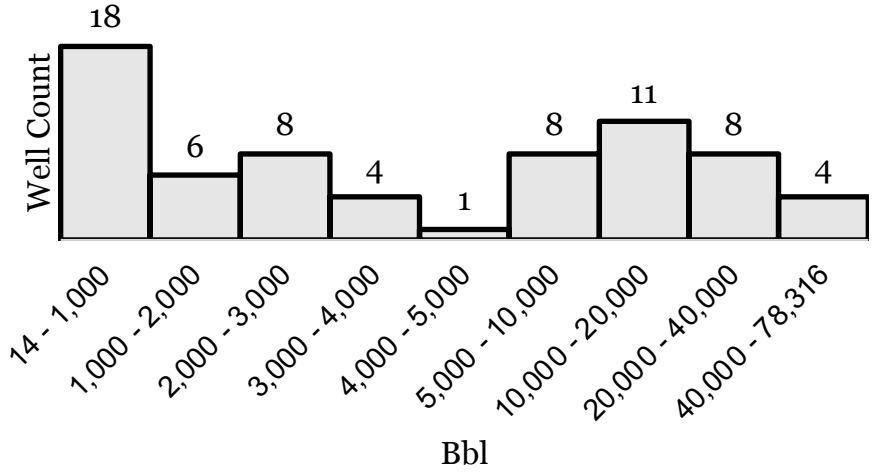
APPENDIX E

LOCAL PRODUCTION

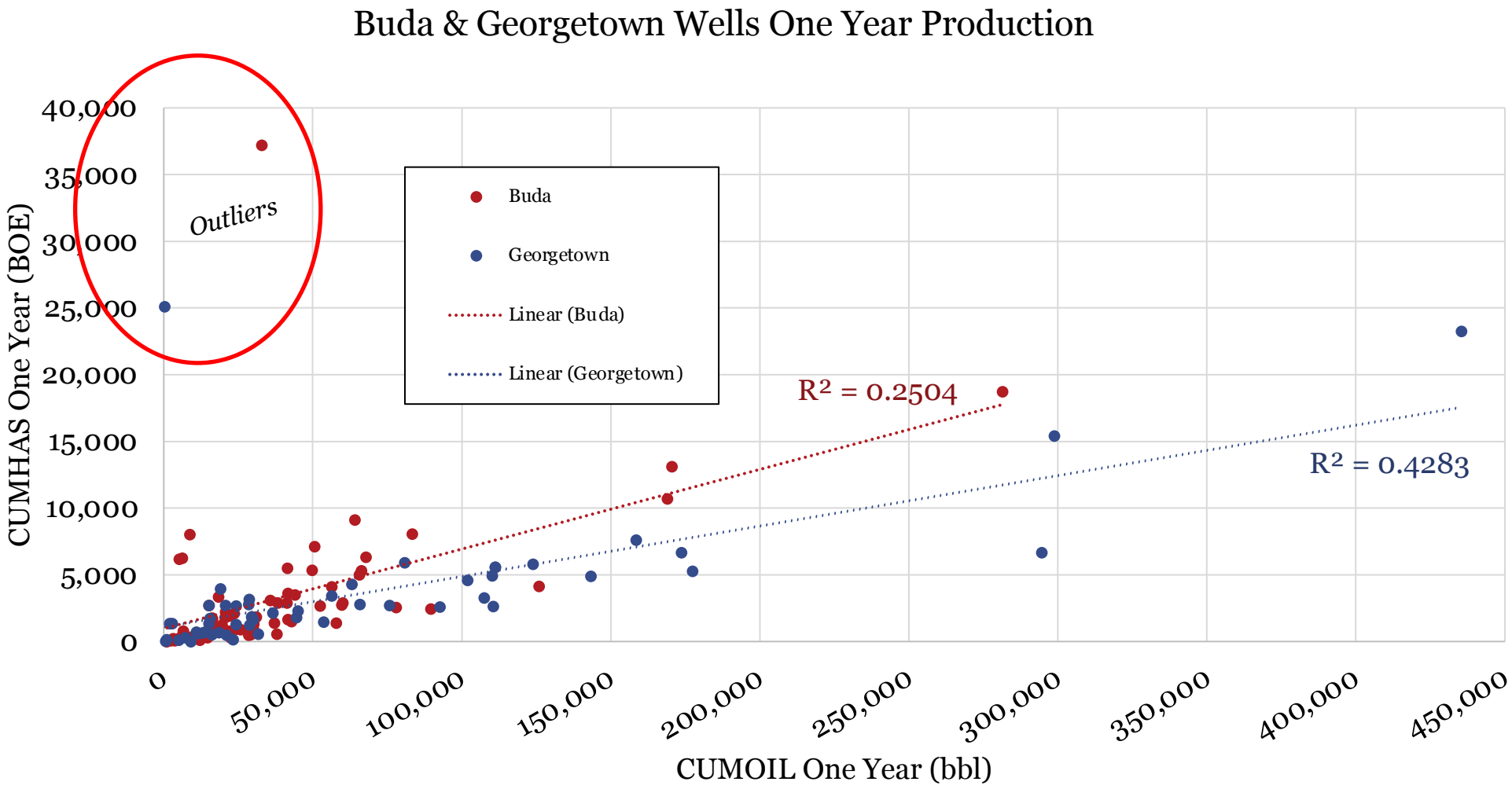








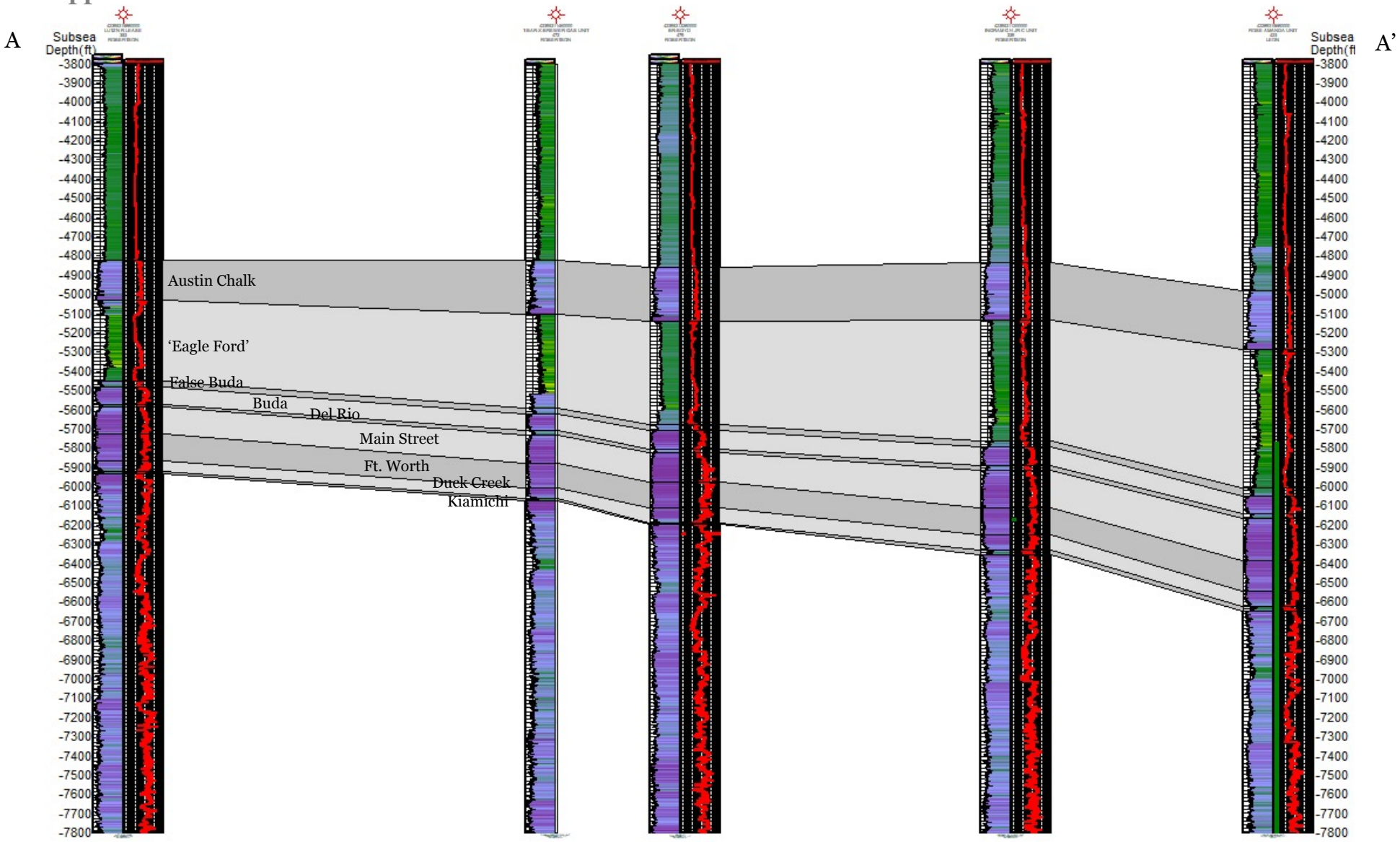
LOCAL PRODUCTION



APPENDIX F

STRUCTURAL CROSS SECTION

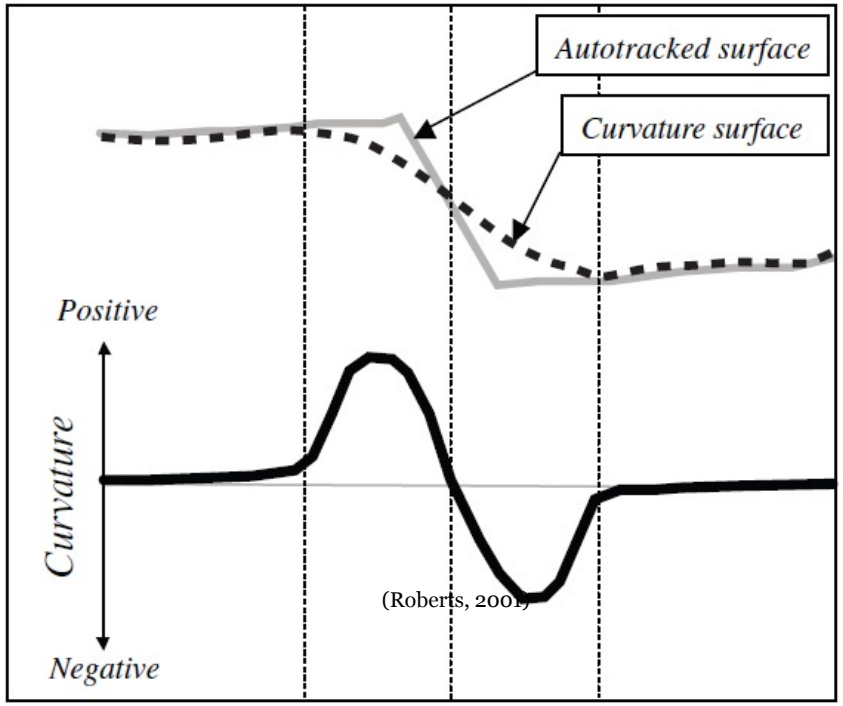
Approximate Strike



APPENDIX H

CURVATURE MAP METHODOLOGY

- Curvature maps can highlight lineation created by faulting which may be associated with natural fractures
- Curvature can be shape dependent or directionally dependent..



(Roberts, 2001)

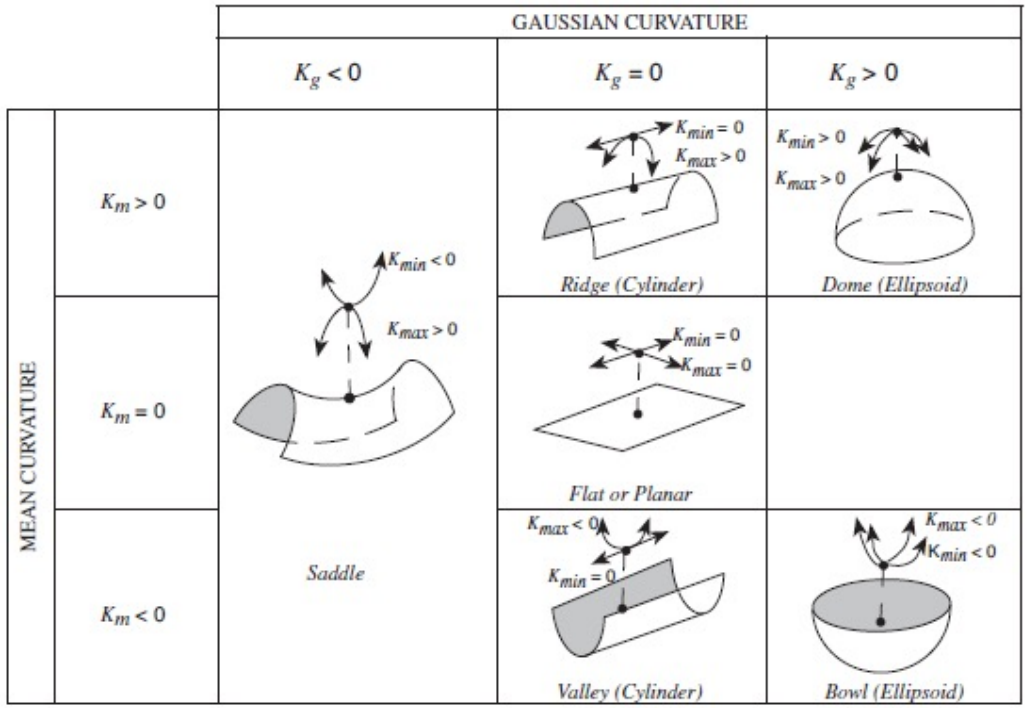


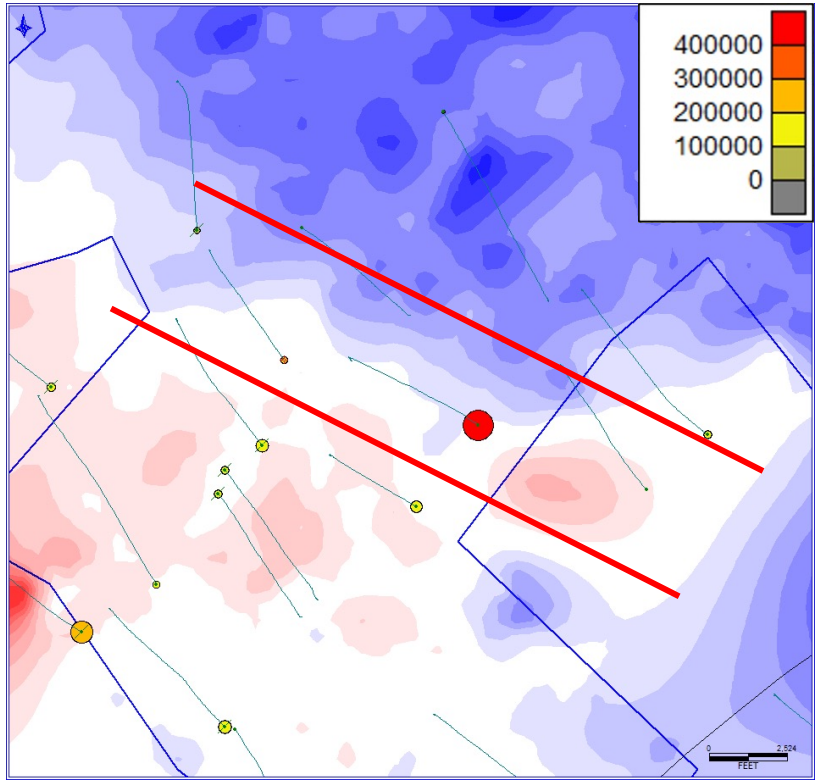
Fig.6 Curvature shape classification. Combination of *mean curvature* and *Gaussian curvature* allows the local shape of a surface to be described.

(Roberts, 2001)

See **APPENDIX A** for additional methodology

INTERCEPTING FRACTURES

- Is the most productive well attributed to following a ‘fairway’ of similar local dip illustrated by the residual trend map?
- Does flexure or fracturing from local dip trends cause formation more susceptible to NE orientation fracturing from regional dip?



Buda, 3rd Order Residual Trend Map