Sequence Stratigraphy of the Ferry Lake Anhydrite, Northeastern Gulf of Mexico: Implications for Hydrocarbon Potential*

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Abstract

The Lower Cretaceous Ferry Lake Anhydrite in southern Mississippi is composed of approximately 76 meters (250 feet) of alternating carbonate and evaporite beds. Correlations of well logs indicate rhythmic depositional stacking of carbonate and anhydrite facies. Identification of these small-scale transgressive-regressive cycles, which formed during high-frequency eustatic sea-level fluctuations, is based on stratal geometry, nature of cycle boundaries, and facies stacking patterns. The Ferry Lake sequence is divided into nine high-frequency, fourth-order parasequences at the southern edge of the Mississippi Interior Salt Basin, and seven high-frequency, fourth-order cycle sets (FLP-1 to FLP-7) approximately 120 kilometers south of the southern rim. Fewer parasequences in the seaward direction result from pinchouts of evaporite beds and interfingering of evaporites with carbonate beds.

Analysis of a carbonate sample from 4,084 meters (13,398 feet) yielded 1.0 wt.% total organic carbon, vitrinite reflectance of 0.88 %, and Tmax of 437 oC. These results indicate that the Ferry Lake is thermally mature and has hydrocarbon generative potential.

Parasequence stacking patterns suggest that the late stage highstand systems tracts, which are composed of evaporite beds, were deposited during a relative drop in sea level, and the transgressive systems tracts, composed of backstepping carbonate beds, were deposited during a minor relative sea-level rise. Classifying individual carbonate and anhydrite beds into high frequency, fourth-order parasequences provides understanding of reservoir, source, and seal distributions at the play and prospect scale.

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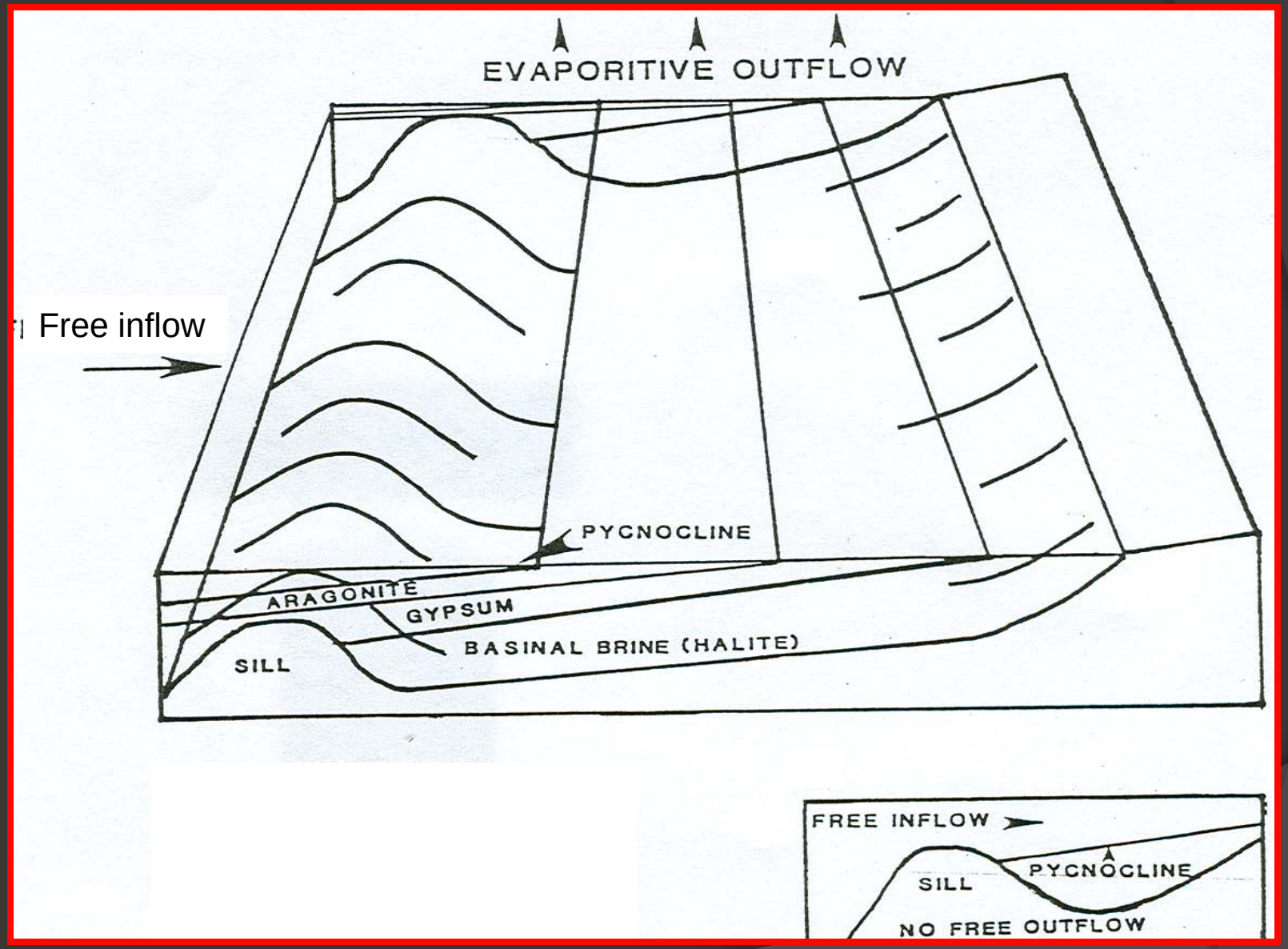
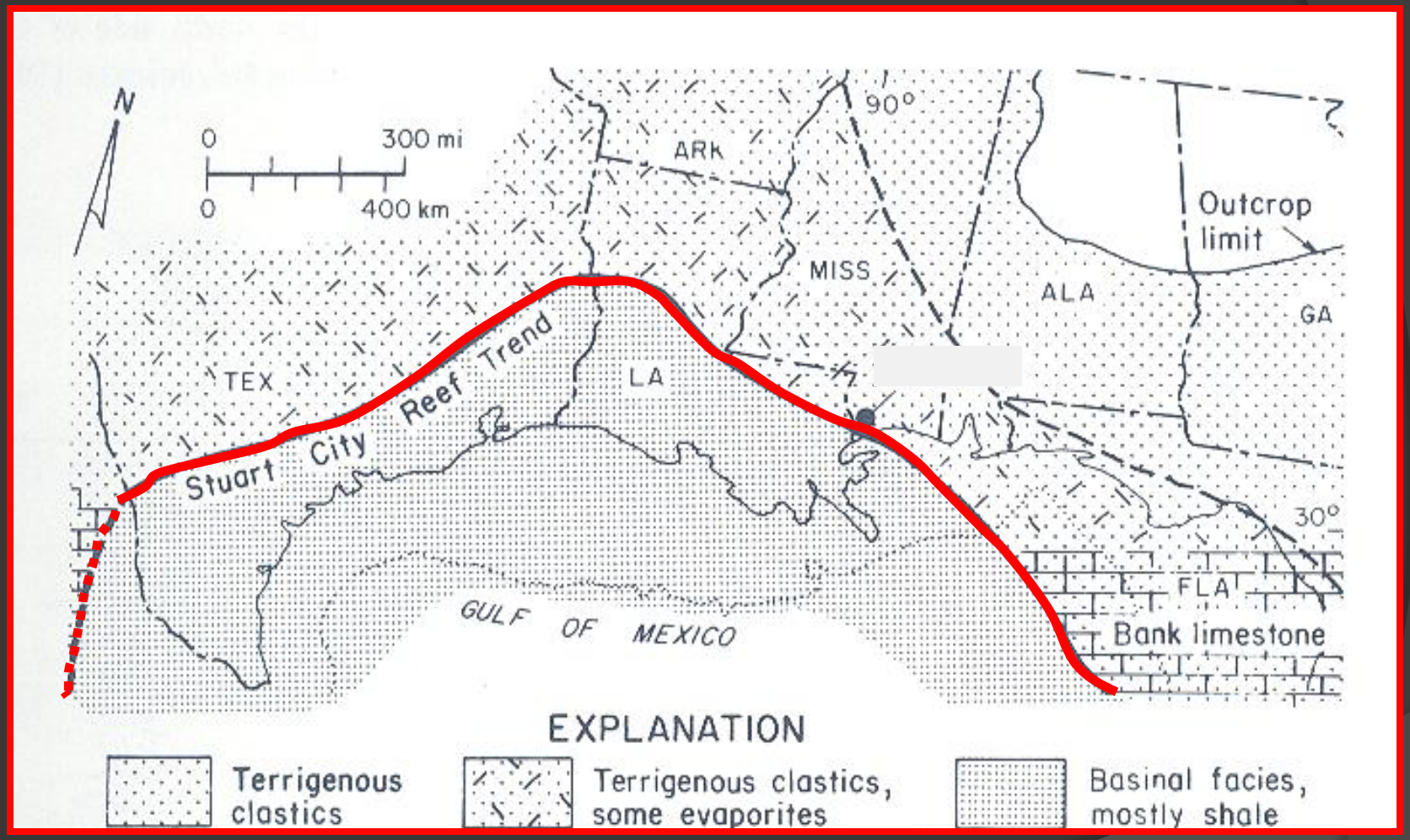
Introduction

- Identify geometric relation of the strata and their stacking patterns
- Develop sequence stratigraphy framework
- Develop an exploration model
- Determine hydrocarbon potential of the FLA

Background Information

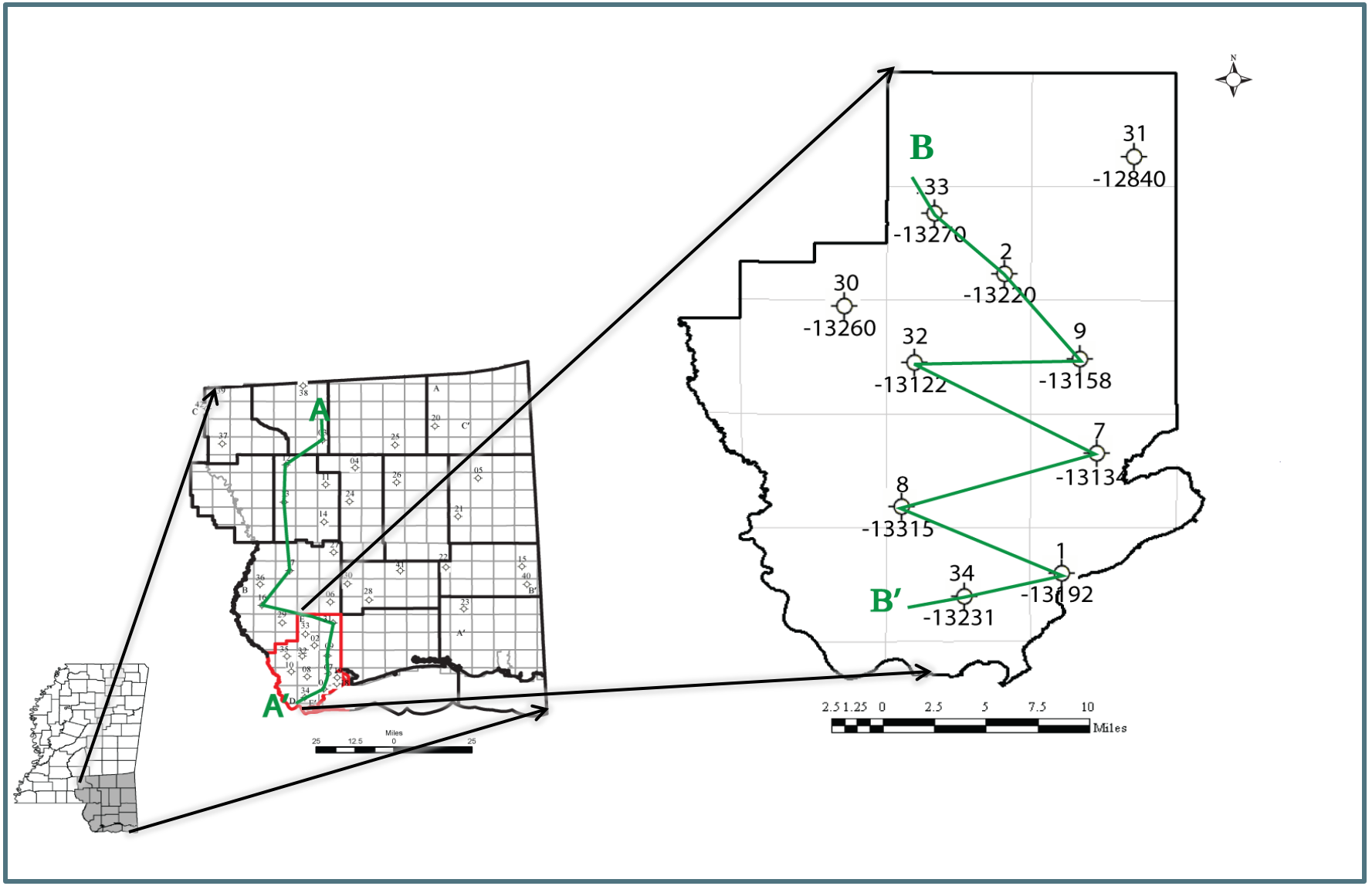
- Deposited during the Lower Cretaceous Period
- Deposited in a stratopycnal free-flow exchange basin
- Alternating restriction and circulation with open marine water
- Alternate deposit of limestone and evaporite beds


EVAPORITIVE OUTFLOW
Free inflow
PYCNOCLINE
ARAGONITE
GYPSUM
BASINAL BRINE (HALITE)
SILL
FREE INFLOW
SILL
PYCNOCLINE
NO FREE OUTFLOW



(From Duckworth et al., 1992)

<table>
<tr><th colspan="2" rowspan="2">Series</th><th rowspan="2">Stage</th><th rowspan="2">Group</th><th colspan="2">Formation</th></tr>
<tr><th>Outcrop</th><th>Onshore and Offshore Gulf of Mexico</th></tr>
<tr><td rowspan="5">Lower Cretaceous</td><td rowspan="5">Comanchean</td><td rowspan="3">Albian</td><td rowspan="5">Trinity</td><td rowspan="2">DeQueen Formation</td><td>Mooringsport</td></tr>
<tr><td>Ferry Lake</td></tr>
<tr><td rowspan="2">Holly Creek Formation</td><td>Rodessa</td></tr>
<tr><td rowspan="2">Aptian</td><td>James Limestone</td></tr>
<tr><td>Delight</td><td>Pine Island Shale</td></tr>
</table>

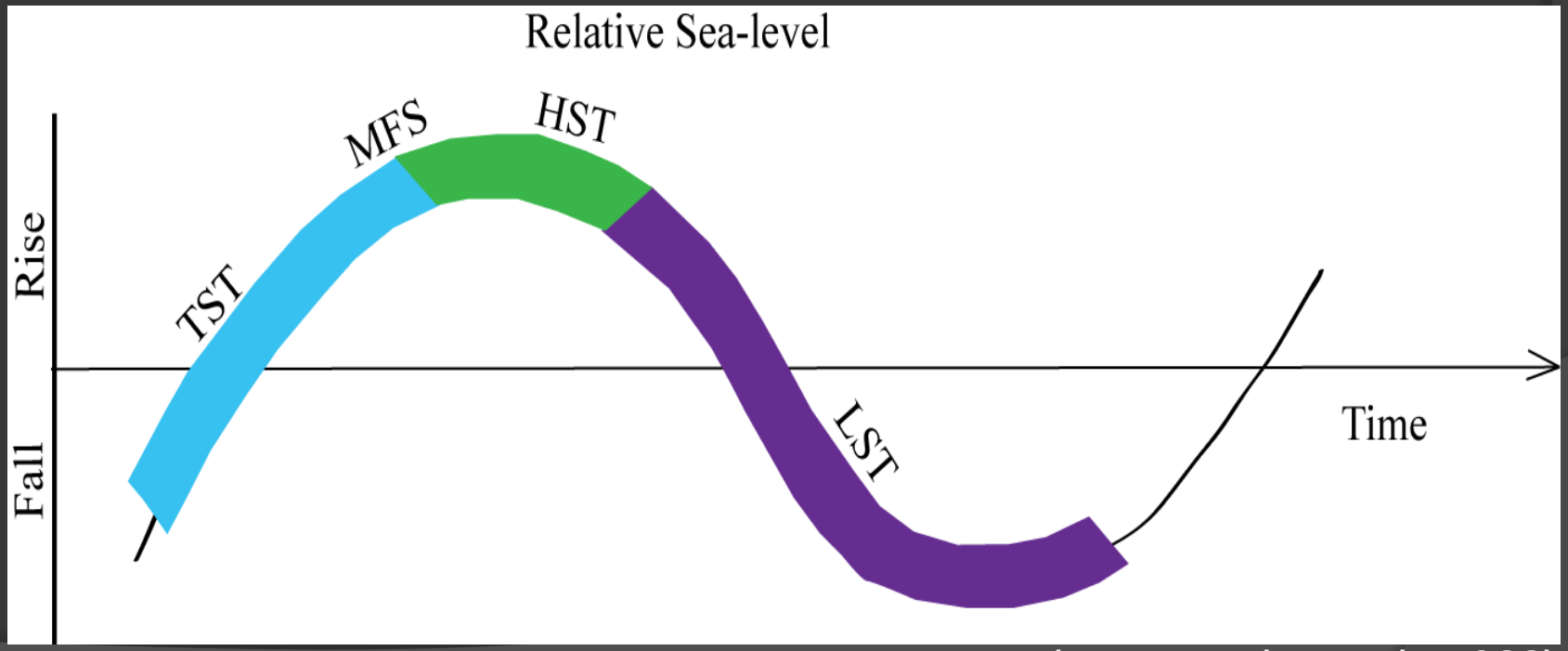

B
31
-12840
33
-13270
2
-13220
30
-13260
32
-13122
9
-13158
7
-13134
8
-13315
1
-13192
34
-13231
B′
2.5 1.25 0 2.5 5 7.5 10
Miles
A
A′
25 12.5 0 25
Miles

Sequence stratigraphy

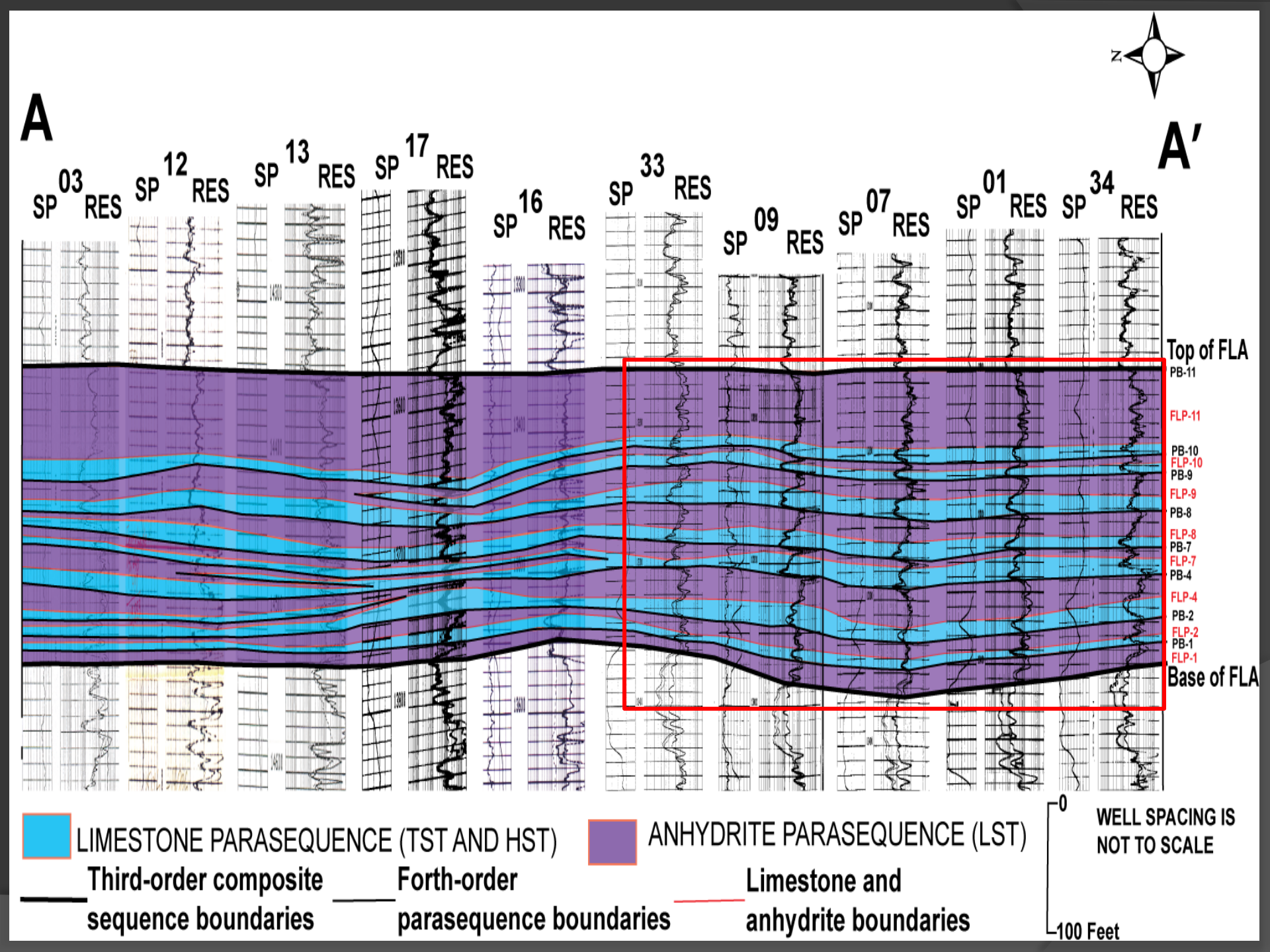
- Sequence — a relatively conformable succession of genetically related strata bounded at its top and base by unconformities or their correlative conformities (Posamentier and James, 1993)
- Parasequence — a relatively conformable succession of genetically related beds or bedsets bounded by marine flooding surfaces or their correlative surfaces (Van Wagoner et al., 1990)

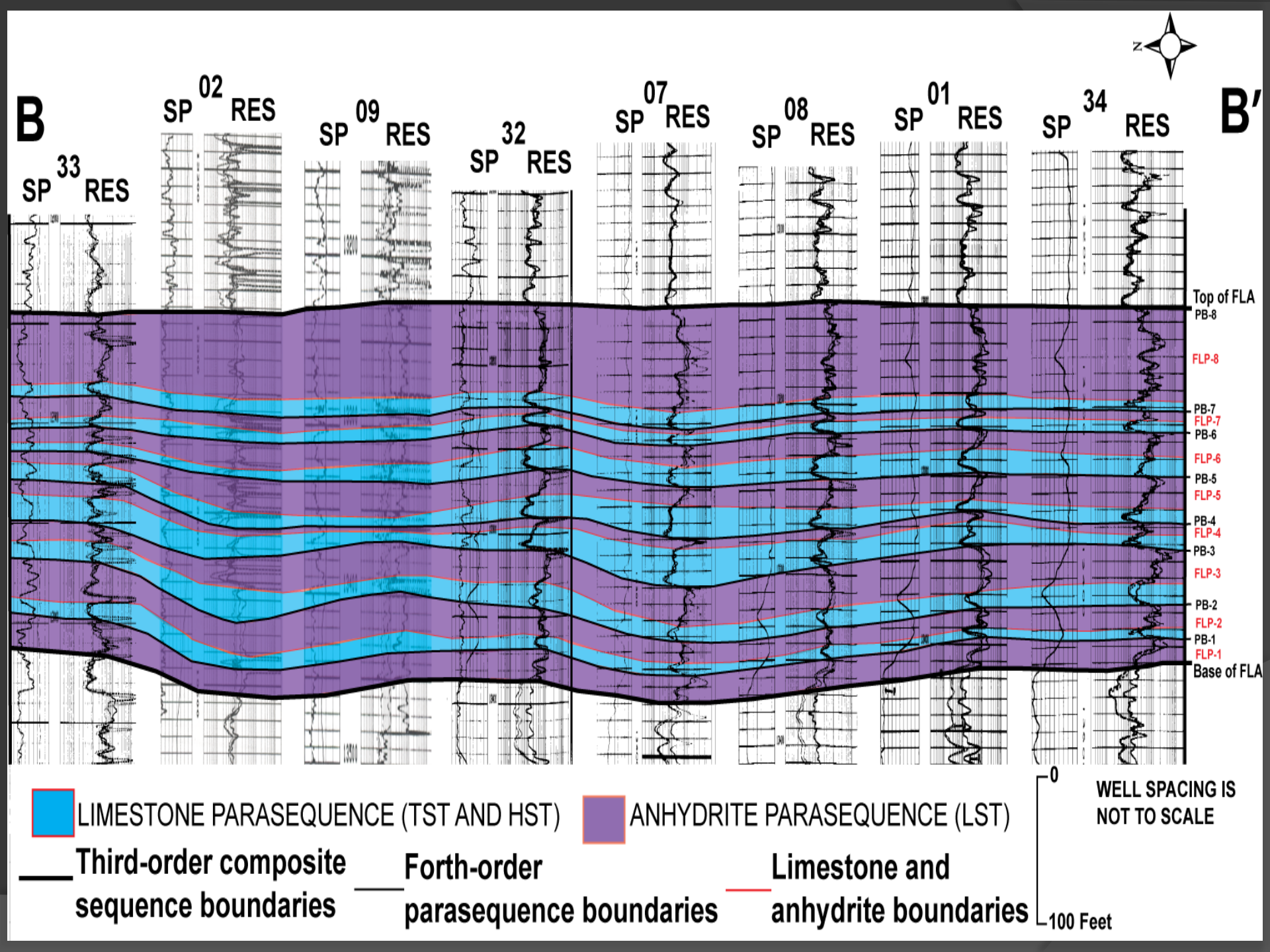
Application to Ferry Lake Anhydrite

- Transgressive systems tracts (TST)
- Lowstand systems tracts (LST)
- High systems tracts (HST)
- Maximum flooding surfaces (MFS)



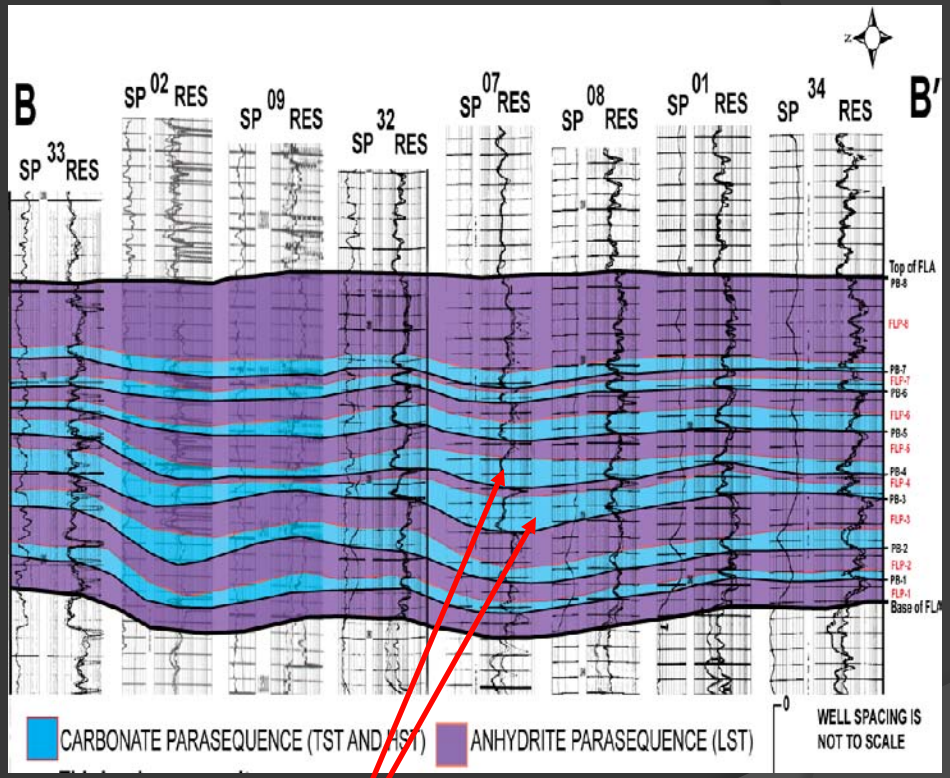
(Posamentier et al., 1988)


A
A′
SP 03 RES
SP 12 RES
SP 13 RES
SP 17 RES
SP 16 RES
SP 33 RES
SP 09 RES
SP 07 RES
SP 01 RES
SP 34 RES
Top of FLA
PB-11
FLP-11
PB-10
FLP-10
PB-9
FLP-9
PB-8
FLP-8
PB-7
FLP-7
PB-4
FLP-4
PB-2
FLP-2
PB-1
FLP-1
Base of FLA
LIMESTONE PARASEQUENCE (TST AND HST)
ANHYDRITE PARASEQUENCE (LST)
Third-order composite sequence boundaries
Forth-order parasequence boundaries
Limestone and anhydrite boundaries
0
100 Feet
WELL SPACING IS NOT TO SCALE


B
B′
SP 33 RES
SP 02 RES
SP 09 RES
32 SP RES
SP 07 RES
SP 08 RES
SP 01 RES
SP 34 RES
Top of FLA
PB-8
FLP-8
PB-7
FLP-7
PB-6
FLP-6
PB-5
FLP-5
PB-4
FLP-4
PB-3
FLP-3
PB-2
FLP-2
PB-1
FLP-1
Base of FLA
LIMESTONE PARASEQUENCE (TST AND HST)
ANHYDRITE PARASEQUENCE (LST)
Third-order composite sequence boundaries
Forth-order parasequence boundaries
Limestone and anhydrite boundaries
0
100 Feet
WELL SPACING IS NOT TO SCALE

Geochemical analysis

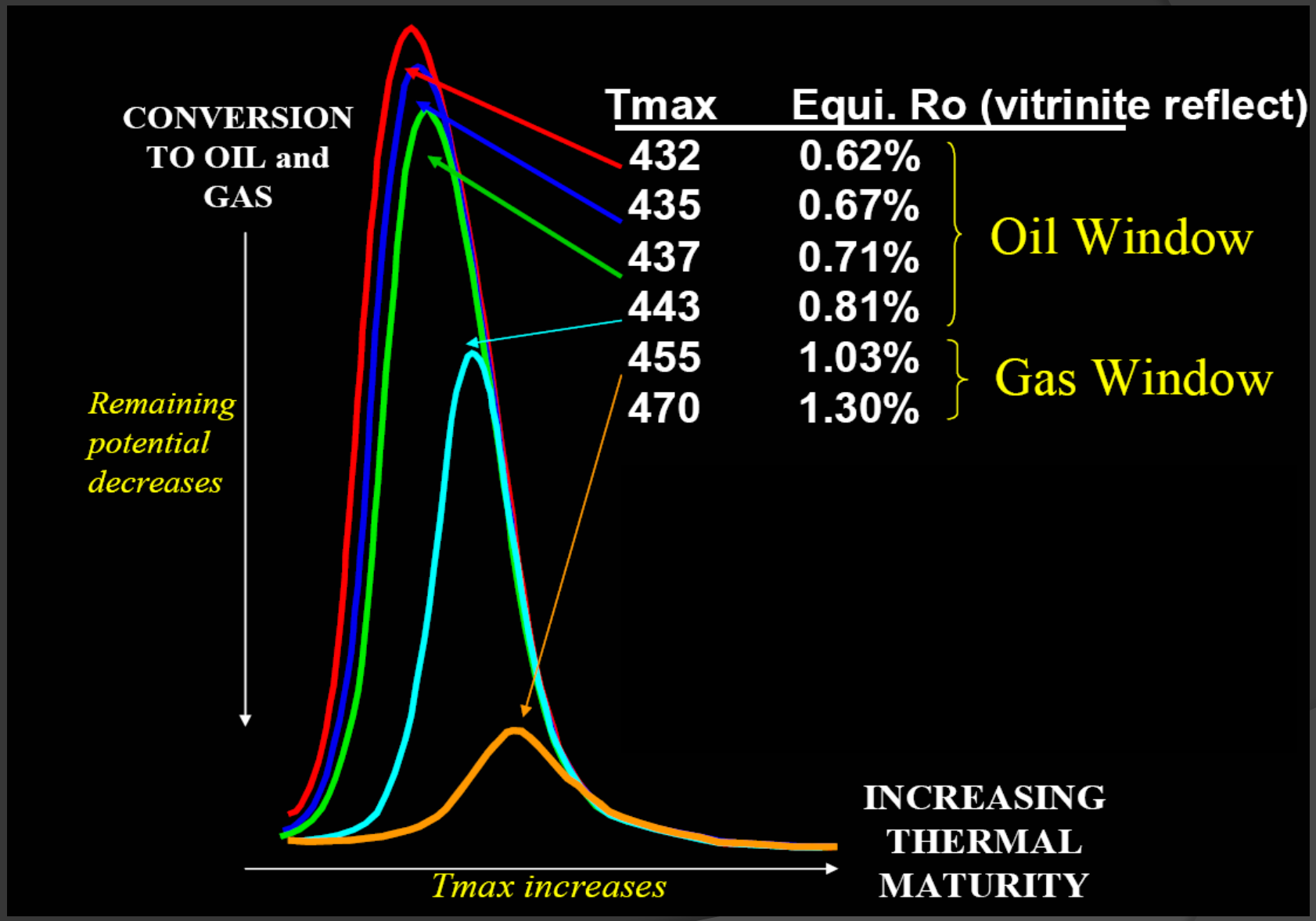
- TOC analysis
- Rock-Eval Pyrolysis
  - Vitrinite reflectance (%Ro)
  - Visual kerogen
  - Thermal alteration index (TAI)



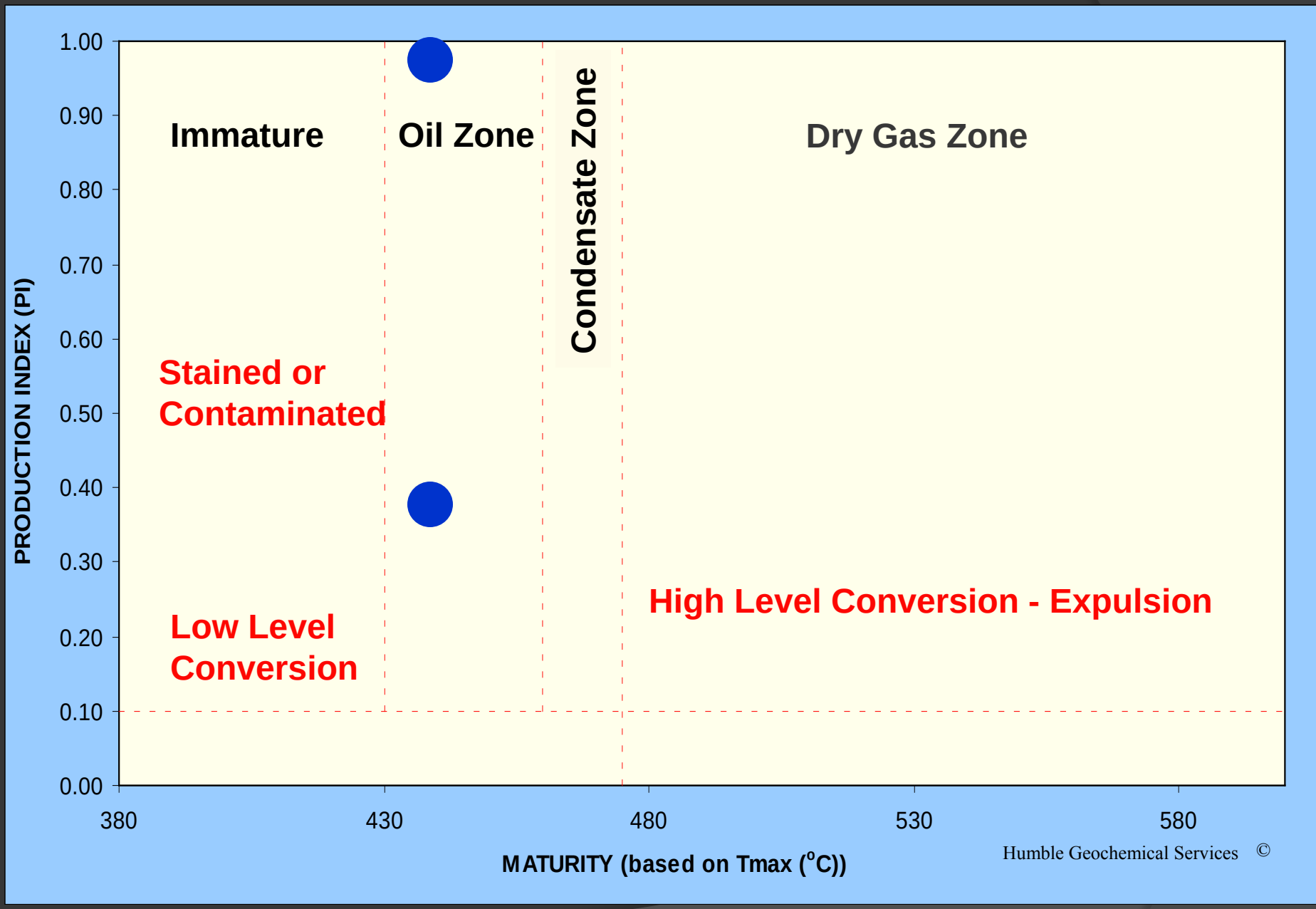
Sample locations

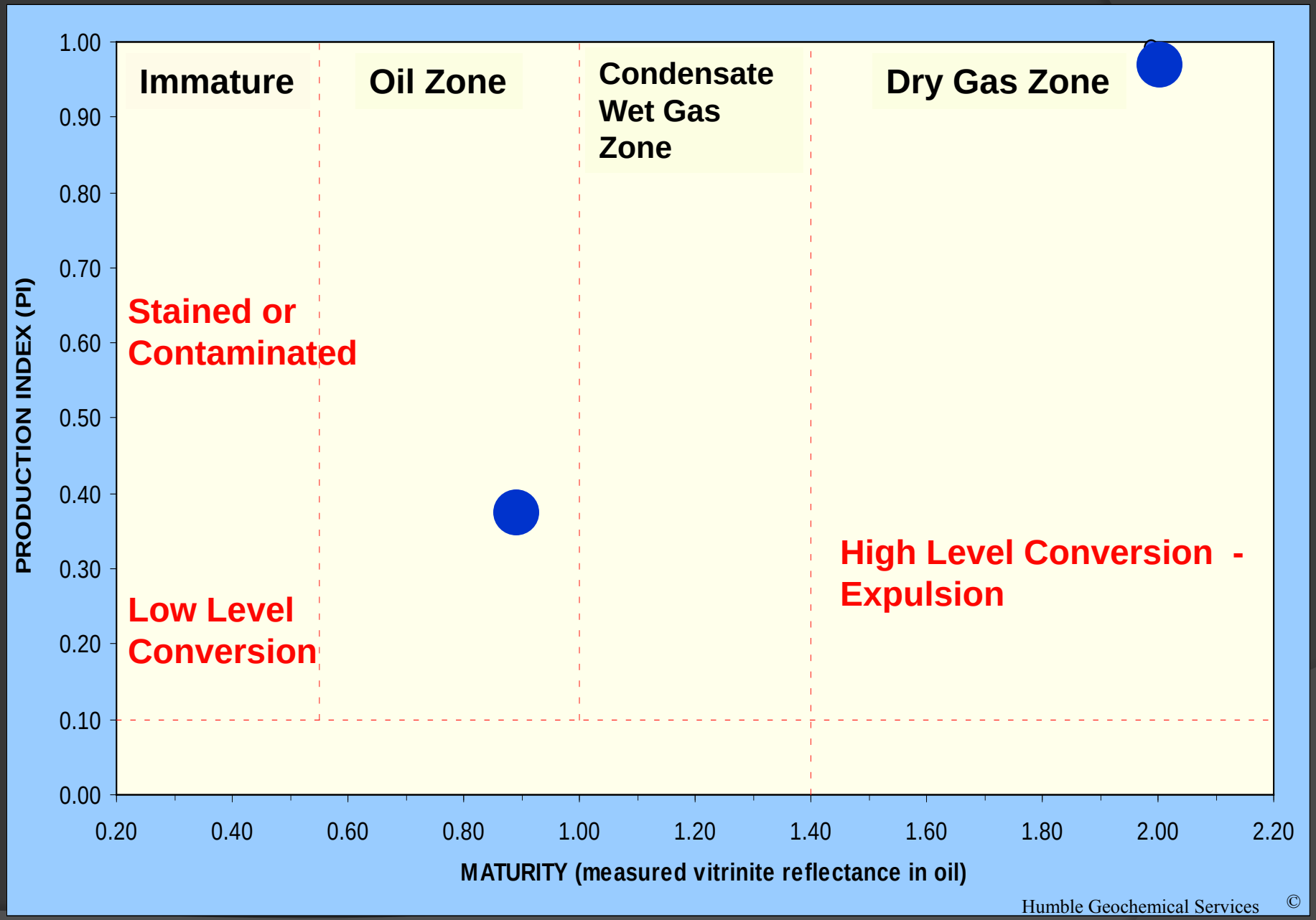
Results

SAMPLES	Leco TOC	Tmax (^{0}C)	Calc. %Ro	Meas. %Ro	PI
FOA_01	0.53	437	0.71	0.88	0.38
FOA_02	1.00	438	0.72	1.99	0.99



(Humble Geochemical Services)


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
PRODUCTION INDEX (PI)
Immature
Oil Zone
Condensate Zone
Dry Gas Zone
Stained or Contaminated
Low Level Conversion
High Level Conversion - Expulsion
380
430
480
530
580
MATURITY (based on Tmax (°C))
Humble Geochemical Services ©


Immature
Oil Zone
Condensate Wet Gas Zone
Dry Gas Zone
Stained or Contaminated
Low Level Conversion
High Level Conversion - Expulsion
PRODUCTION INDEX (PI)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
MATURITY (measured vitrinite reflectance in oil)
Humble Geochemical Services ©

Conclusions

- Eleven parasequence sets at the north, decreased to eight parasequence sets southward
- Developed limestone beds in parasequence sets 4,7, and 8
- TOC result shows that the formation has a fair to good hydrocarbon generation potential
- Thermal mature source rock placing it within oil and gas generation window

Selected References

Duckworth, R; and D. Rickard, 1992, Evidence for deep crustal porosity from massive sulphide textures, Renstrom, Sweden: International Geological Congress Abstracts Congres Geologique Internationale, Resumes 29, v. 3, 792 p.

Wagoner, J.C. Van, R.M. Mitchum, K.M. Campion, V.D. Rahmanian, 1990, Siliciclastic Sequence Stratigraphy in Well Logs, Cores, and Outcrops: Concepts for High-Resolution Correlation of Time and Facies, AAPG Methods in Exploration Series No. 7, p. 3-55.