Seismic modeling of fluid substitution in carbonates, Alberta

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CREWES

Outline

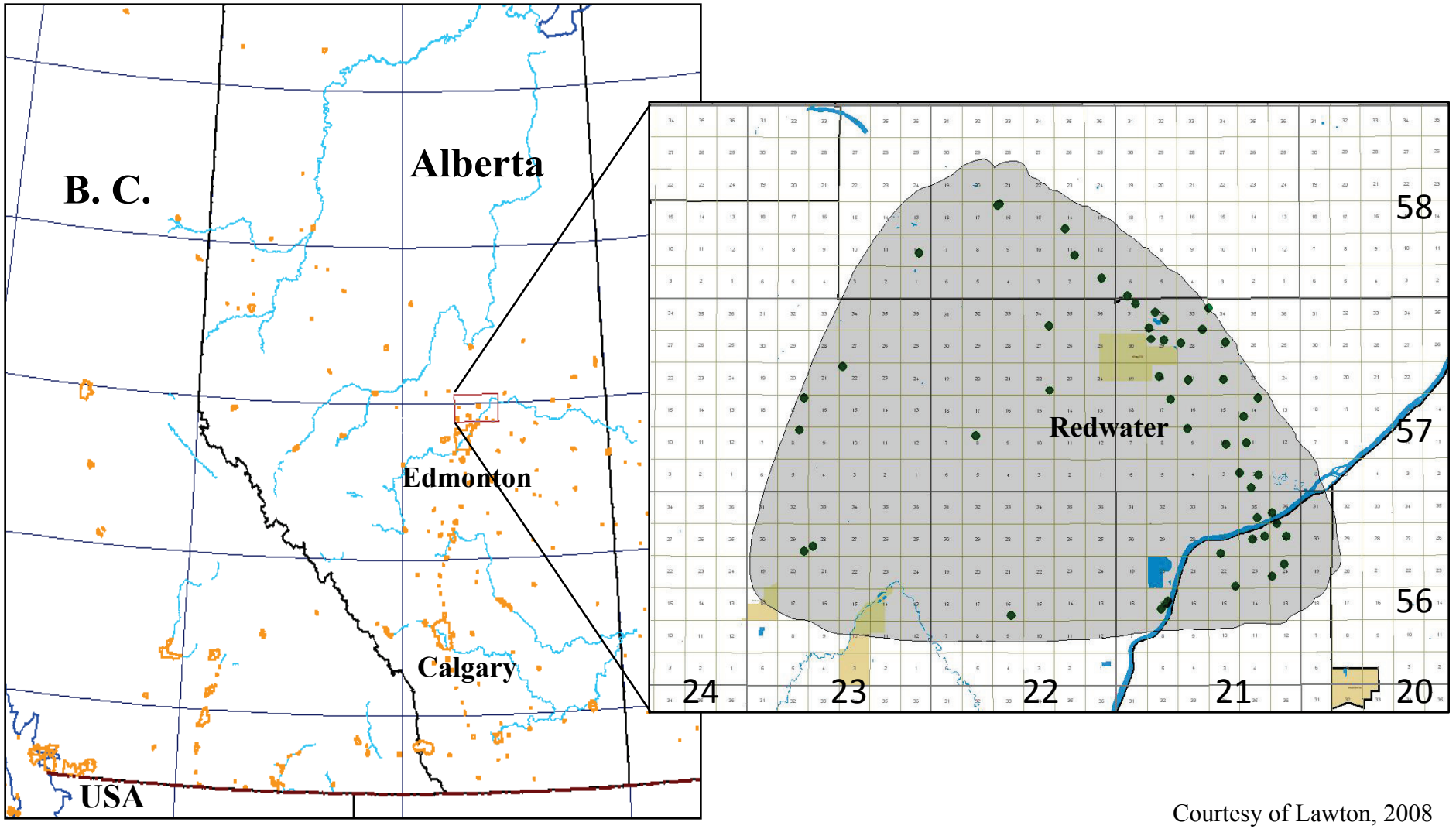
- Objectives and study area
- Geological background
- Redwater reef overview
- Methods
- Results
- Conclusions

Objectives/Method

Evaluate seismic response to CO_2 replacement of brine in Redwater carbonate reef

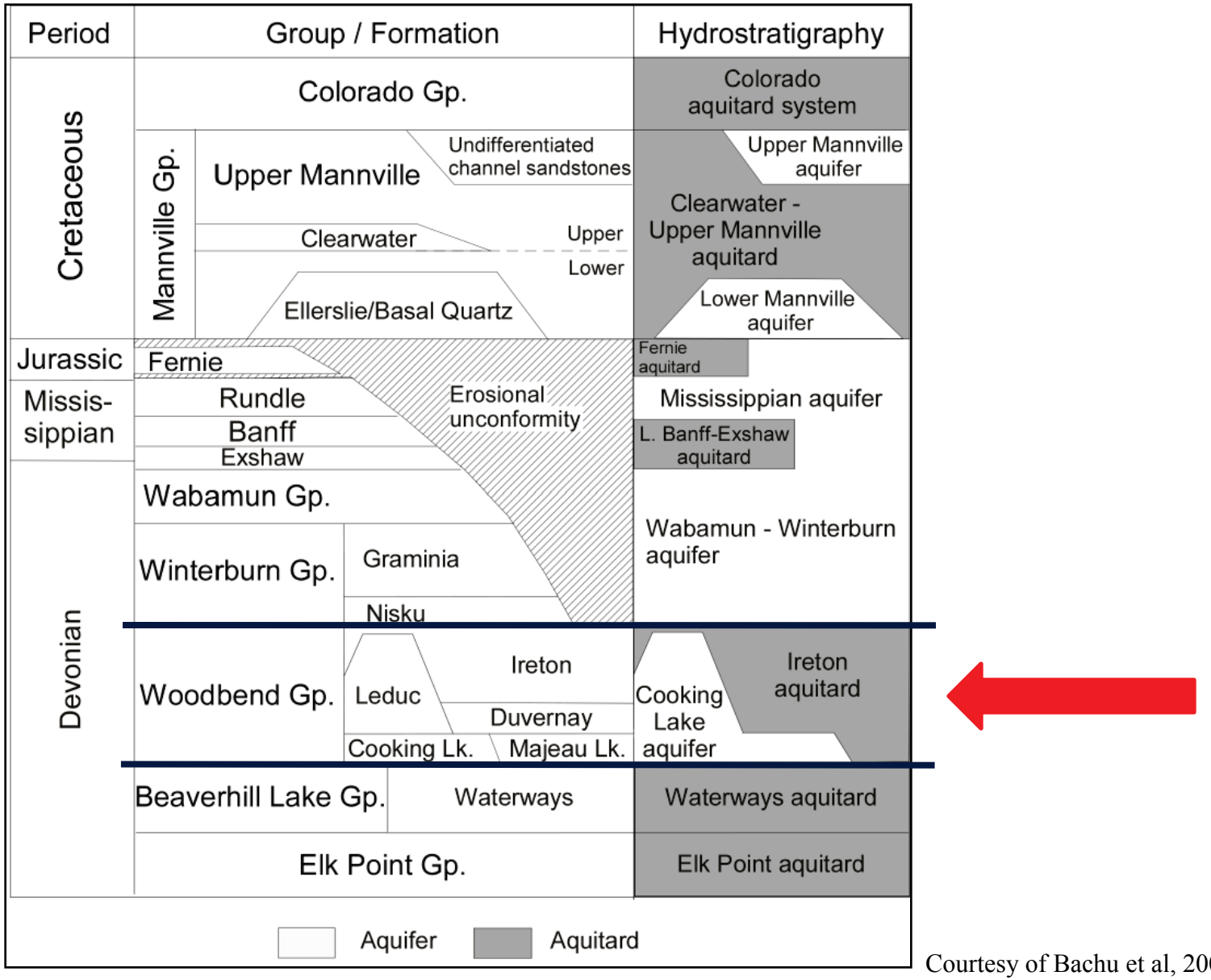
- **Evaluate rock properties from well logs**
- **Determine porosity**
- **Gassman fluid substitution**
- **Changes in velocity**
- **Changes in reflectivity**

Redwater reef study area



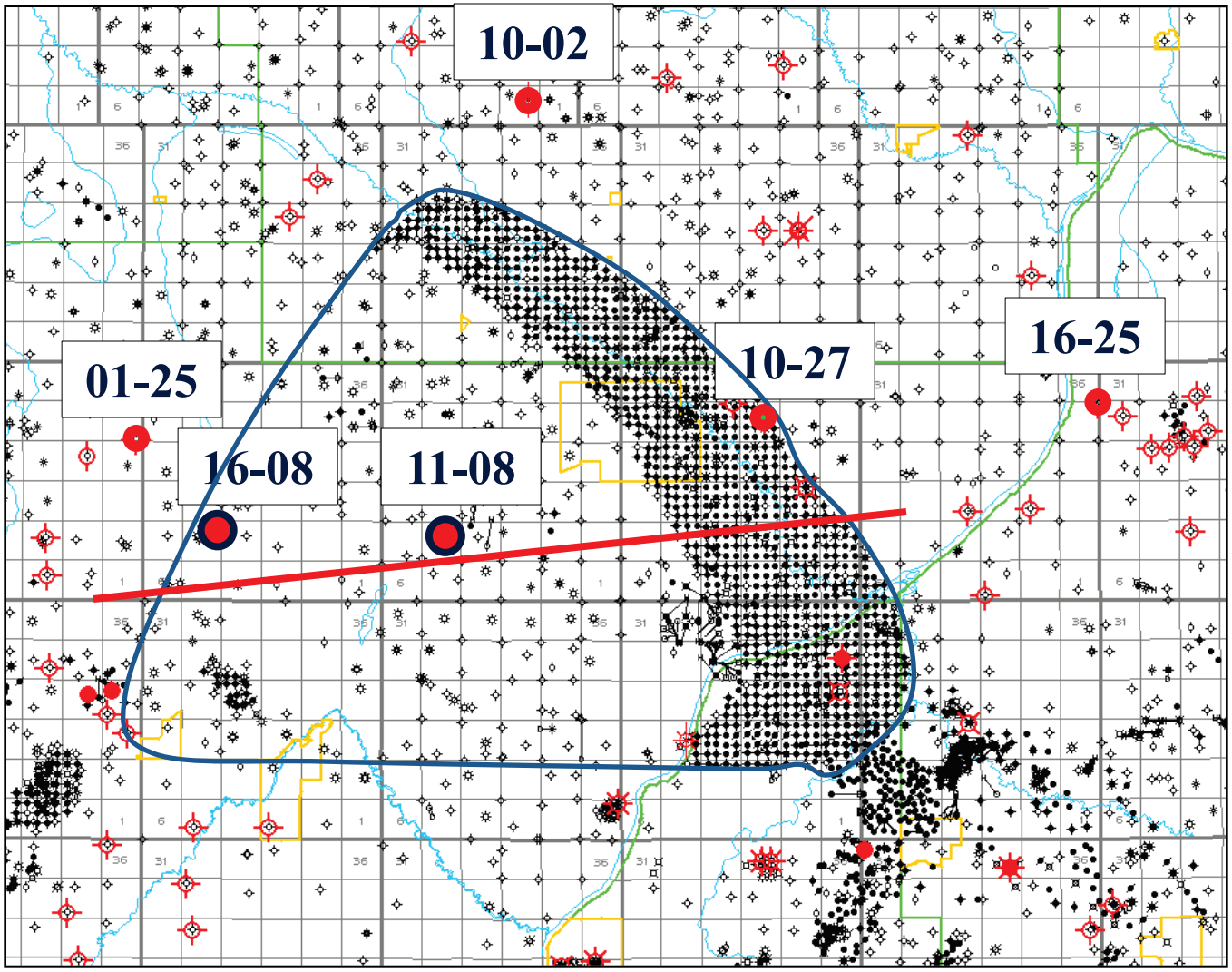
Courtesy of Lawton, 2008

Geological setting

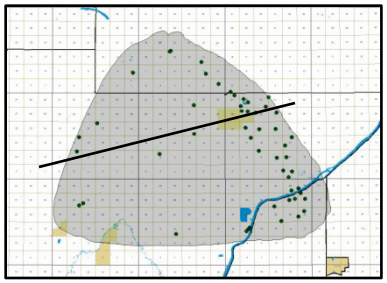


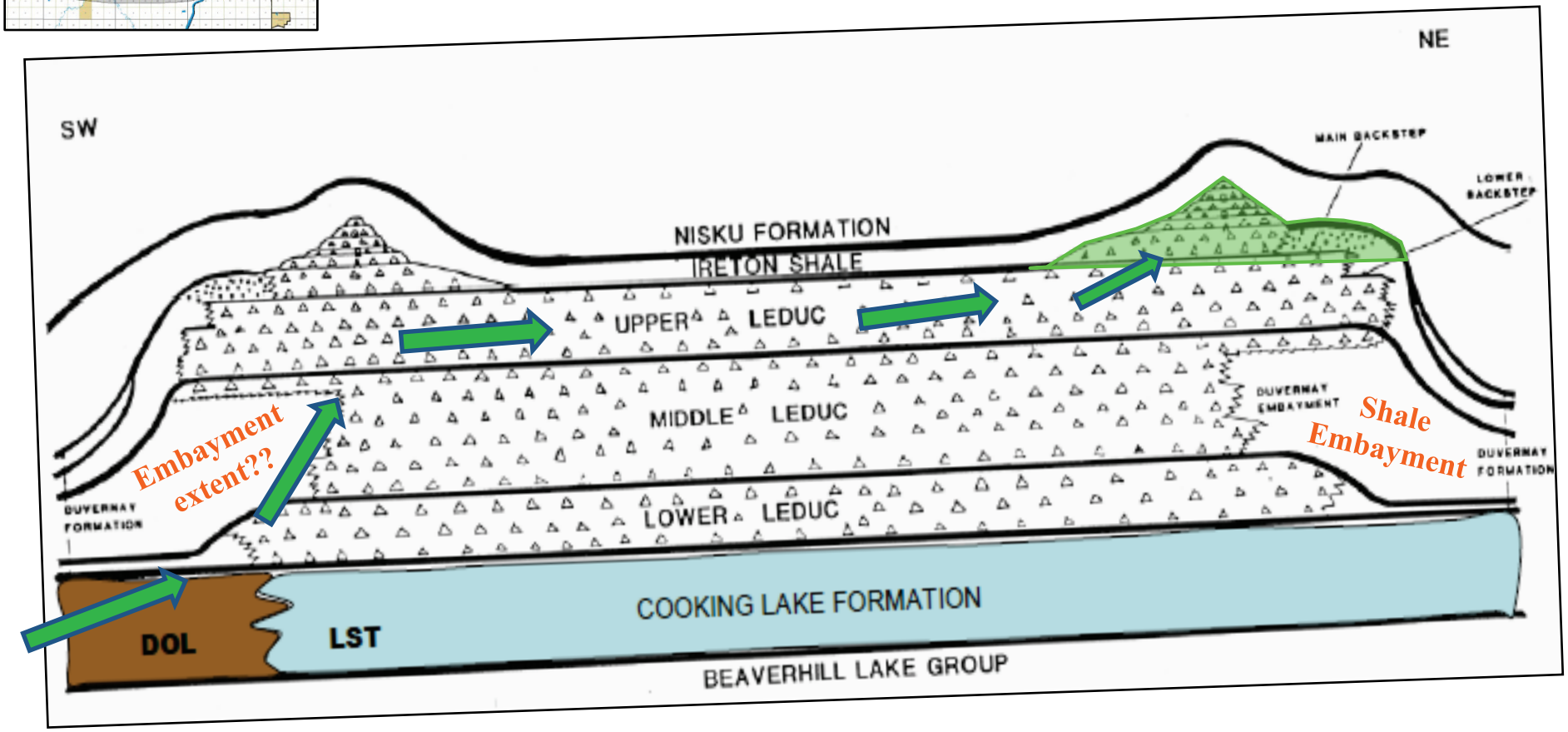
Courtesy of Bachu et al, 2008

Redwater reef key wells



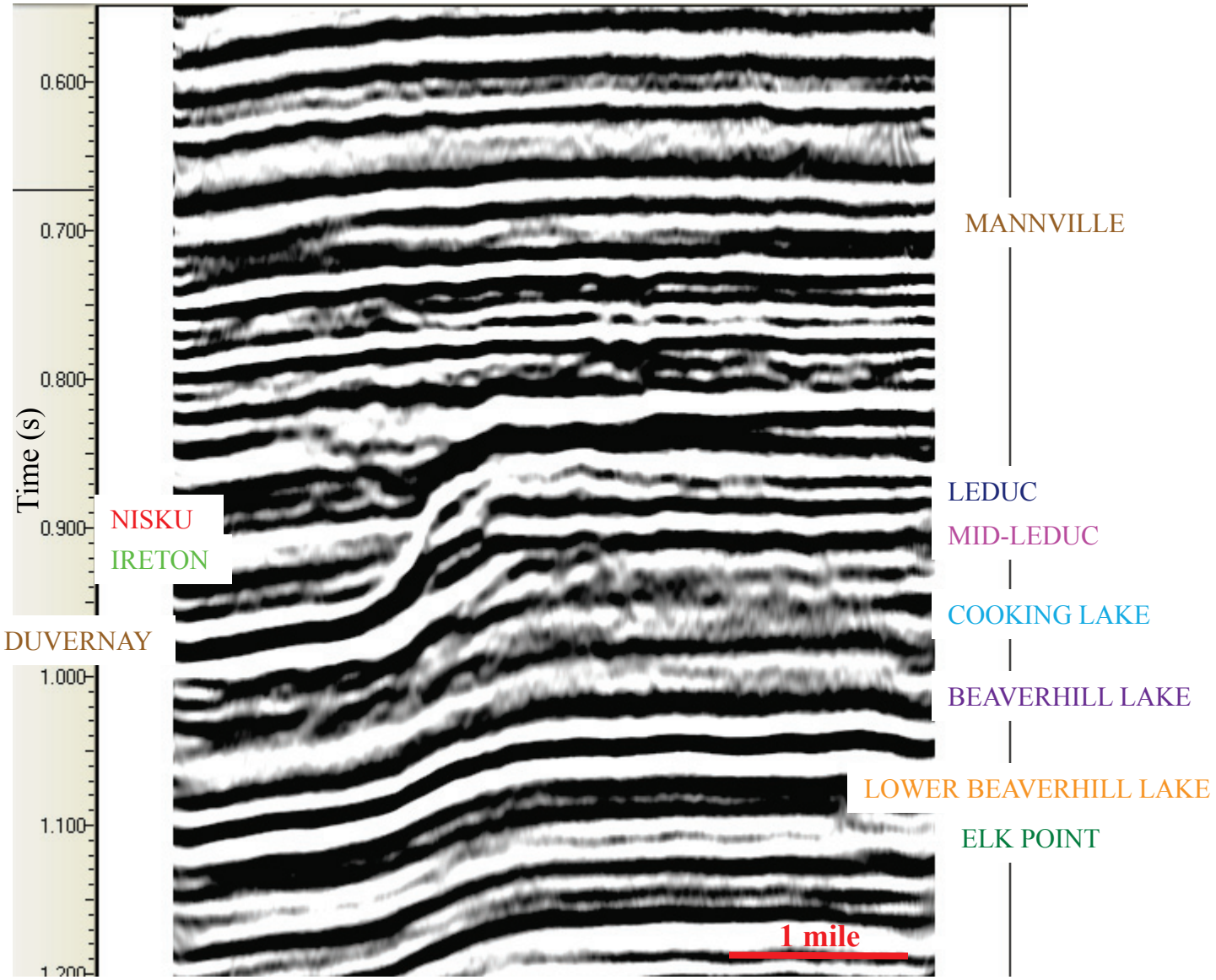
Reef subdivisions and HC migration





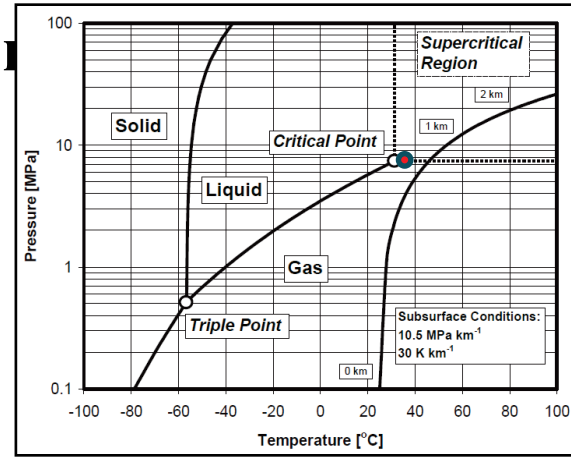
Courtesy of Stoakes and Foellmer, 2008

North-south Seismic Line



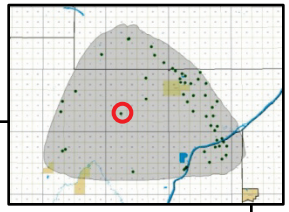
Leduc Formation properties

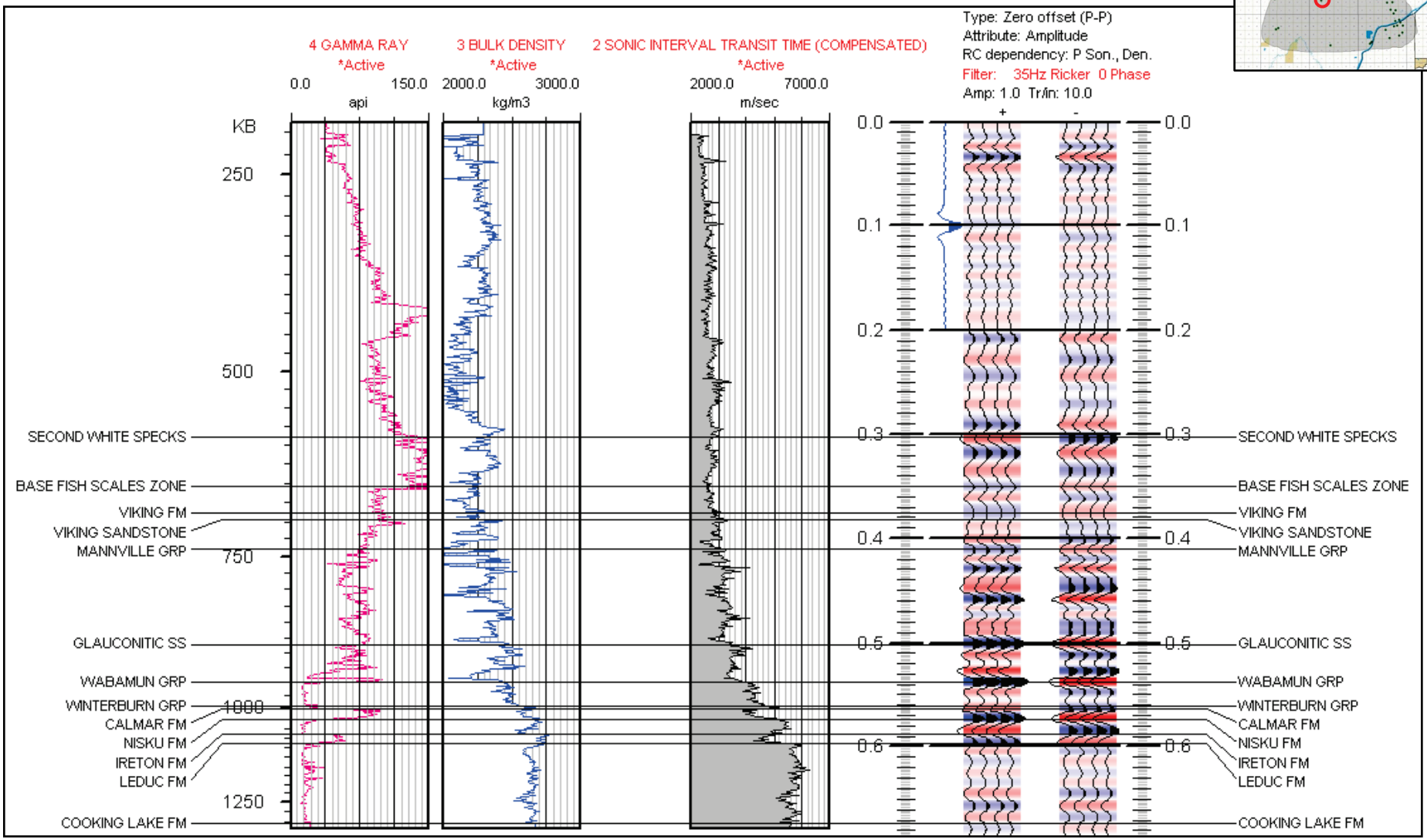
- **Porosity: 1-17% (Avg. 7%)**
  - **Intercrystalline, molding, and fractu**
- **Permeability:**
  - **Horizontally: 0.01-4000 md**
  - **Vertically: 0.02-670 md**



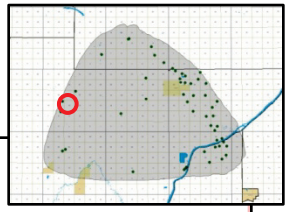
- **Pressure 7.4 MPa and Temperature 34°C**
- **Formation water NaCl, salinity 107 mg/l**
- **Leduc depth: 994 - 1120 m**

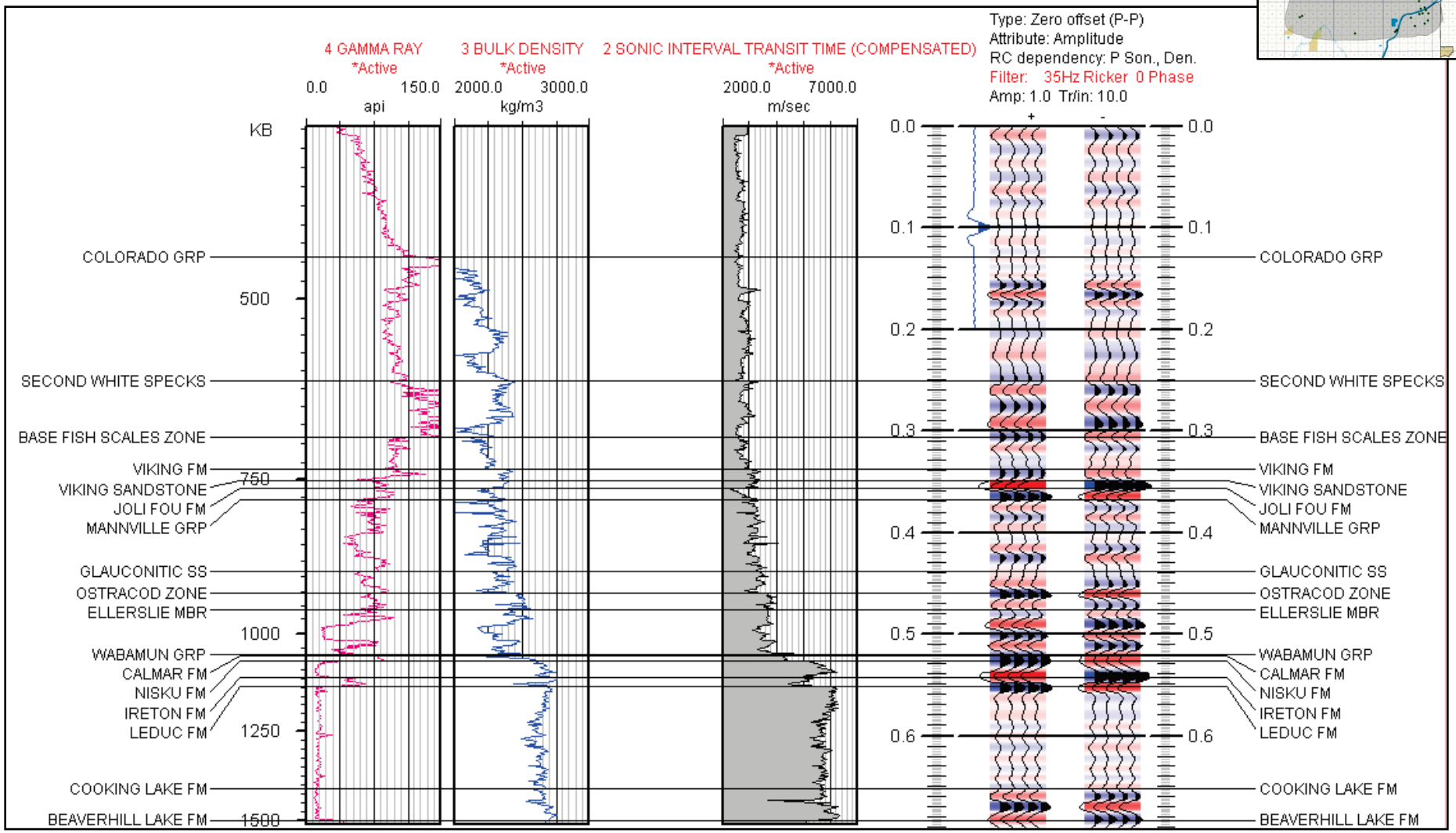
Well 11-08-57-22W4





Well 16-08-57-23W4





Gassmann fluid substitution modeling

$$K_{sat} = K^* + \frac{\left[1 - \frac{K^*}{K_o}\right]^2}{\frac{\emptyset}{K_{fl}} + \frac{(1-\emptyset)}{K_o} + \frac{K^*}{{K_o}^2}}$$

$K_{sat} = \rho_b [V_p^2 - (4/3) V_s^2]$

$\mu_{sat} = \rho_b V_s^2$

$\emptyset = (\rho - \rho_m) / (\rho_{fl} - \rho_m)$

$\rho_{fl} = \rho_w S_w + \rho_c (1 - S_w)$

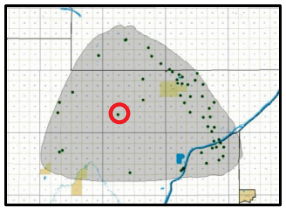
$1/K_{fl} = S_w/K_w + (1-S_w)/K_c$

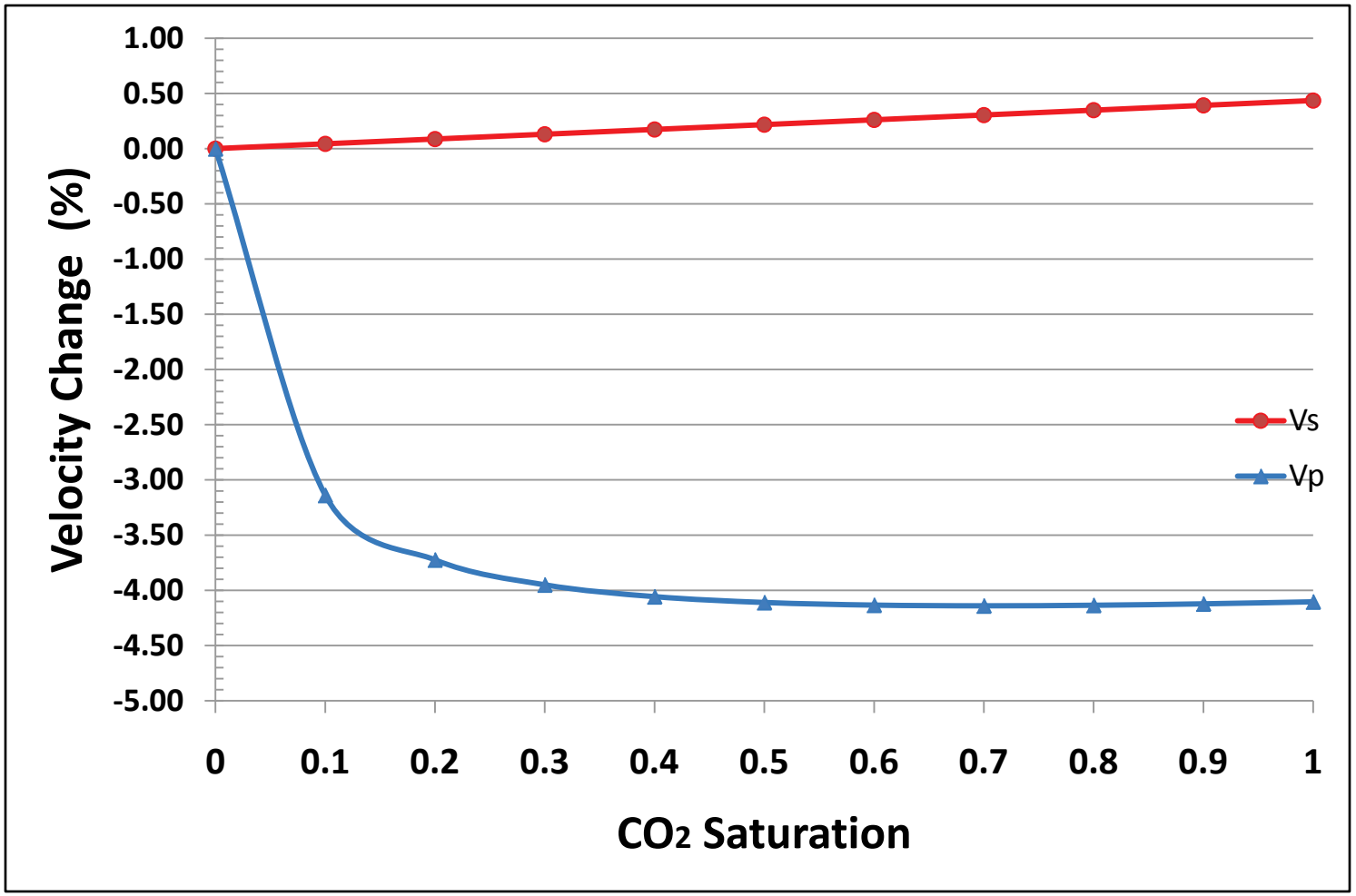
$$V_s^{new} = \sqrt{\frac{\mu_{sat}}{\rho_b^{new}}}$$

$$V_p^{new} = \sqrt{\frac{K^{new}sat + \frac{4}{3}\mu_{sat}}{\rho_b^{new}}}$$

$\rho_b^{new} = \rho_{fl} \emptyset + \rho_m (1-\emptyset)$

FRM Results of Well 11-08



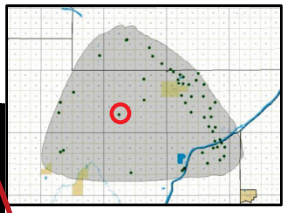


Ø= 4%

K_o= 76 GPa

K*= 47 GPa

FRM Results of Well 11-08



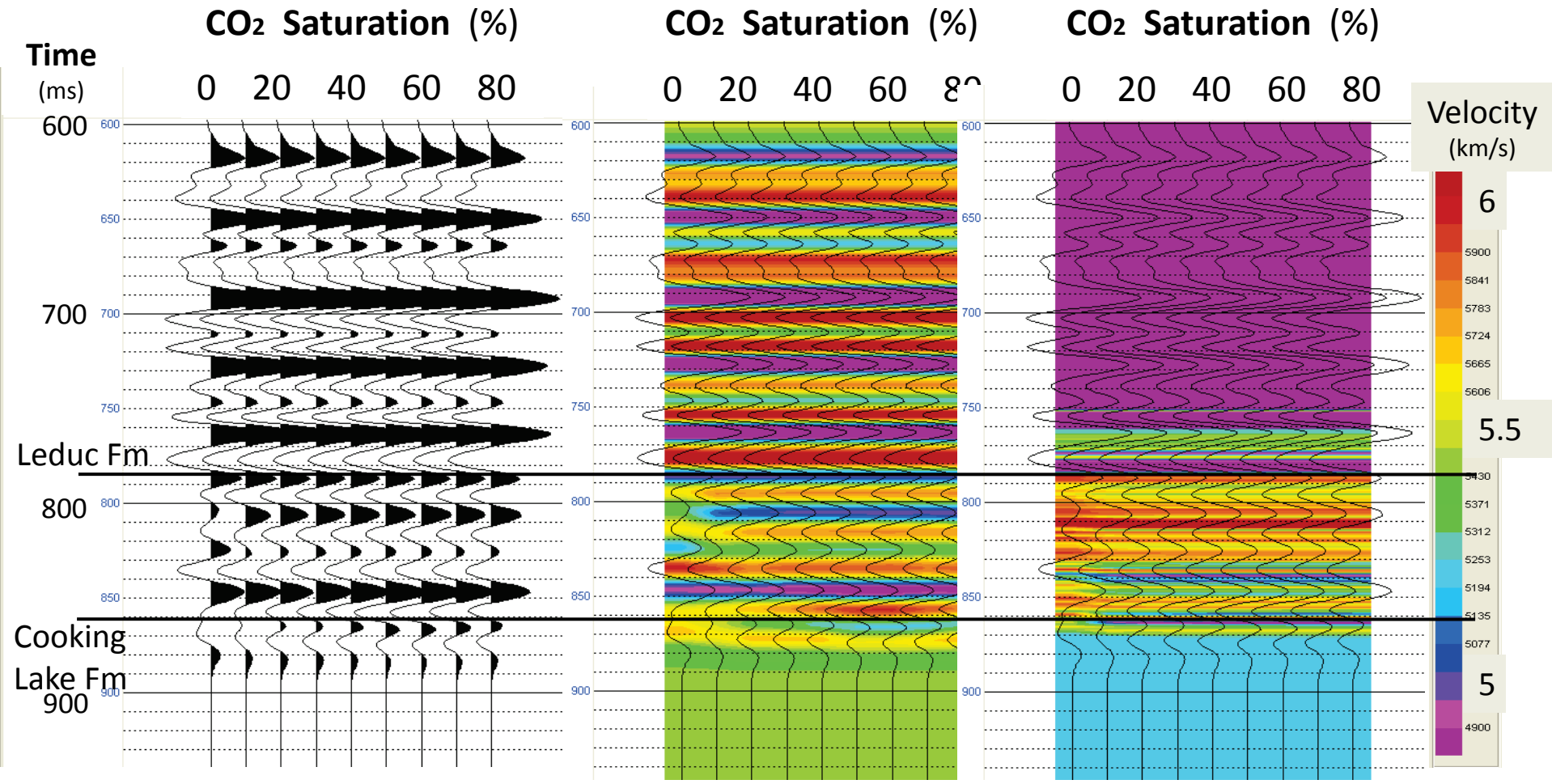
CO2 Saturation	Fluid Density (g/cc)	Rock Density (g/cc)	K_{fl} Gpa	K_{sat} Gpa	V_p m/s	V_s m/s	Vp Change %	Vs Change %	Vp/Vs Change %	Δt (ms)
0	1.07	2.64	2.86	55.08	5747	3025	0	0	0	0
0.1	1.02	2.64	0.76	49.61	5567	3026	-3.14	0.04	-3.18	3.3
0.2	0.96	2.64	0.44	48.55	5533	3027	-3.72	0.09	-3.81	3.9
0.3	0.90	2.64	0.31	48.10	5520	3029	-3.95	0.13	-4.07	4.2
0.4	0.85	2.63	0.24	47.85	5514	3030	-4.06	0.17	-4.22	4.3
0.5	0.79	2.63	0.19	47.70	5511	3031	-4.11	0.22	-4.32	4.4
0.6	0.73	2.63	0.16	47.59	5510	3033	-4.13	0.26	-4.38	4.4
0.7	0.67	2.63	0.14	47.51	5509	3034	-4.14	0.30	-4.43	4.4
0.8	0.62	2.63	0.12	47.45	5509	3035	-4.13	0.35	-4.47	4.4
0.9	0.56	2.62	0.11	47.40	5510	3037	-4.12	0.39	-4.50	4.4
1	0.50	2.62	0.10	47.36	5511	3038	-4.10	0.44	-4.52	4.3
Average	0.76	2.63	0.26	47.91	5519	3032	-3.96	0.24	-4.19	4.2

Ø= 4%

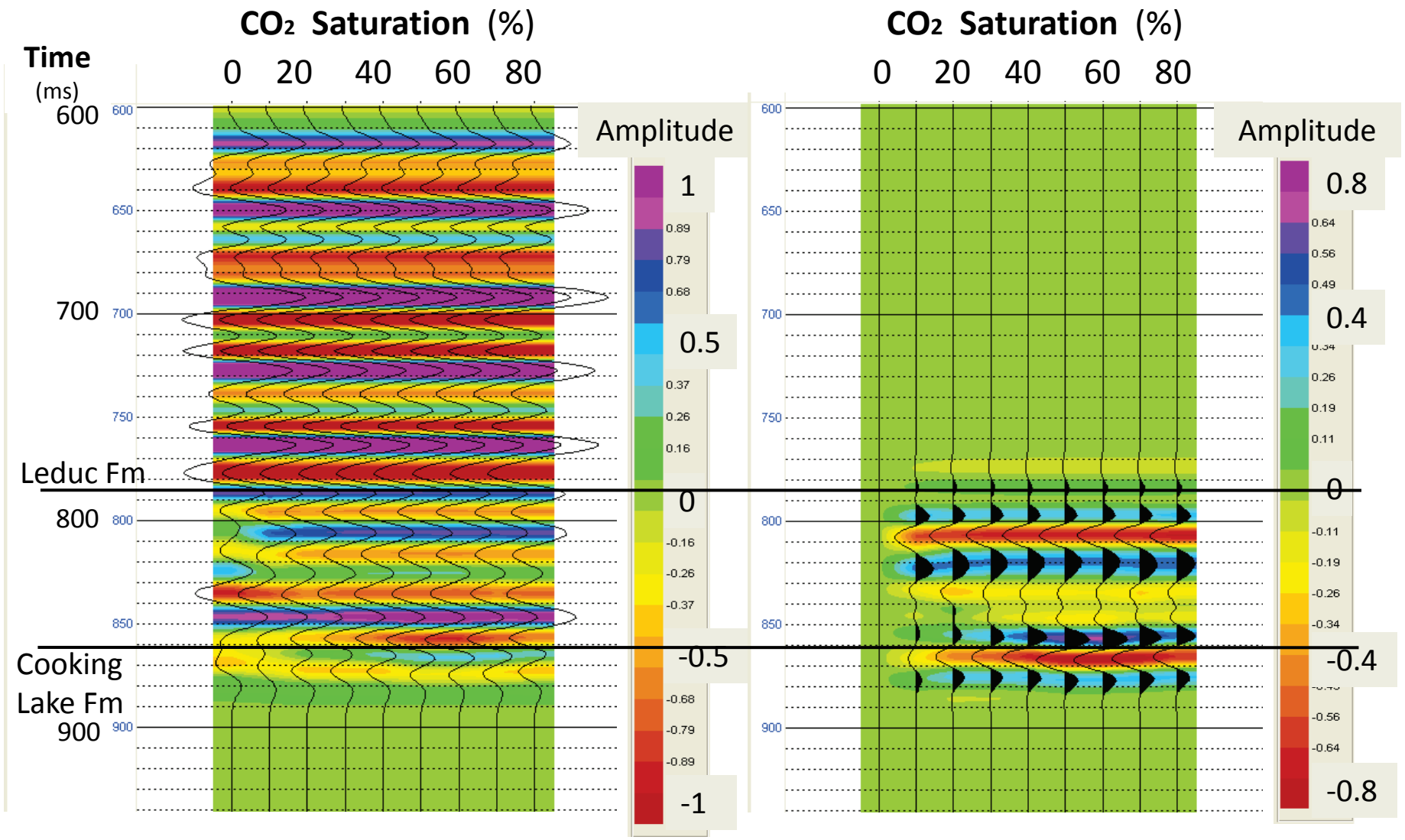
K_o= 76 GPa

K*= 47 GPa

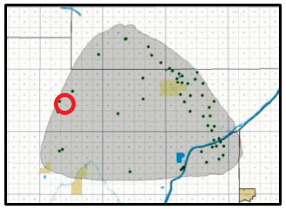
FRM Synthetic of Well 11-08

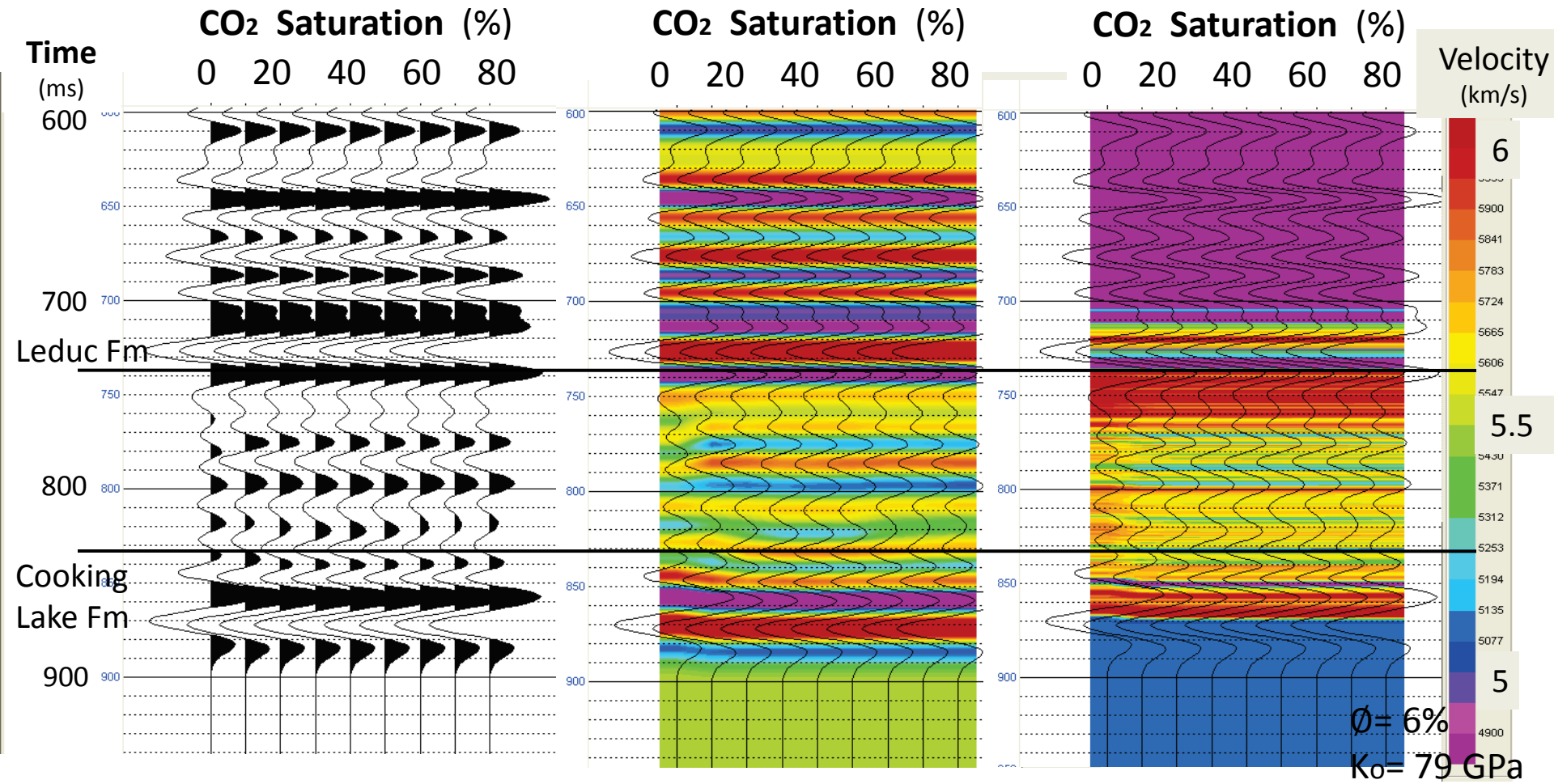


FRM of Well 11-08 with Differences

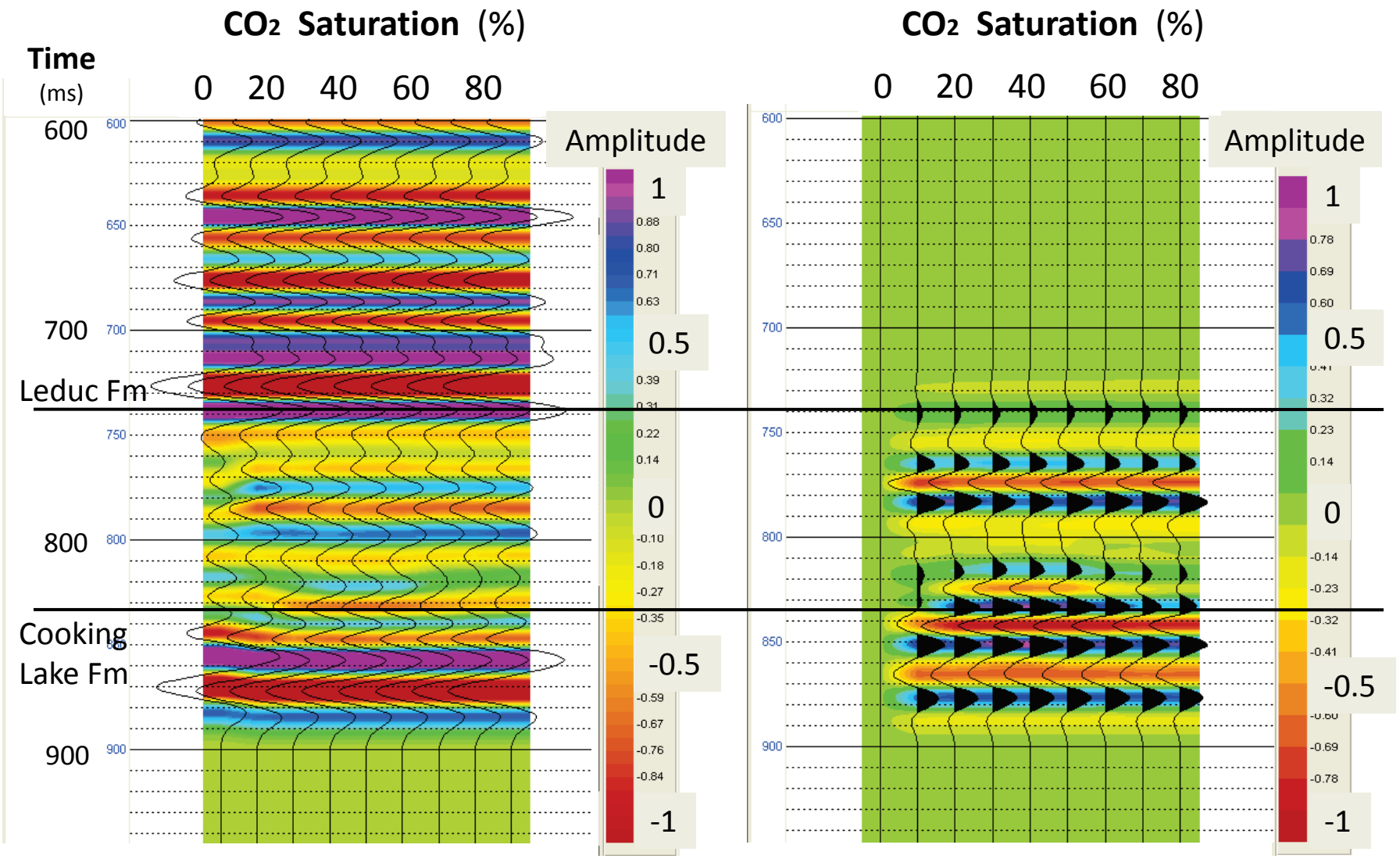


FRM Synthetic of Well 16-08





FRM of Well 16-08 with Differences



Conclusions

- P-wave velocity drops by 2-4% from 0-40% of CO_2
- Slight change from 40-100% of CO_2 in velocity
- Less than 1% increase in S-wave velocity
- 3-4.5% decrease in V_p/V_s
- Observed time shift by about 4 ms caused by CO_2
- Change in amplitude occurred

Acknowledgements

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References

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